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INSTRUCTION MANUAL

model 1501
PROGRAMMABLE PULSE GENERATOR

EH research laboratories, inc.

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INSTRUCTION MANUAL

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PROGRAMMABLE PULSE GENERATOR

Serial No. _____

June 1972

research laboratories, inc.

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All E-H/AMC products are warranted for a period of one year from date of delivery. These products are warranted to be free from defects in material and workmanship, suitable for normal use and service under normal conditions, and able to meet any applicable specifications accepted in writing by E-H/AMC. No claim under the warranty will be accepted unless it is made in writing to E-H/AMC immediately after discovery of defect or in any case, within one year of delivery. No other warranty, express or implied exists outside this warranty. E-H/AMC is not liable for any commercial losses or other consequential damages incurred or sustained as a result of any defective or nonconforming product. E-H/AMC's obligation with respect to losses is limited, under this warranty, at E-H/AMC's option, either to the replacement (by delivery F.O.B. Oakland, California) or repair of its manufactured products which prove to be defective or nonconforming. This warranty does not apply to any products improperly applied or used or which have been subjected to intentional or negligent misuse or accident, or which have been in any way modified by others without the express written agreement of E-H/AMC. Any product claimed to be defective during the warranty period must be returned to an authorized E-H/AMC repair center, with transportation charges prepaid. The product will be repaired and returned to the purchaser with return transportation prepaid by E-H/AMC. If no defect in the product is found, or if failure is due to misuse or accident, such product will be returned to the purchaser with repair and transportation charges billed collect.

For in-warranty repair of this instrument, contact E-H Research Laboratories, Inc., Customer Service Department and provide:

a. Instrument model number and serial number.

b. Details concerning the nature of the malfunction.

Shipping instructions, or repair information and parts will be sent to you promptly.

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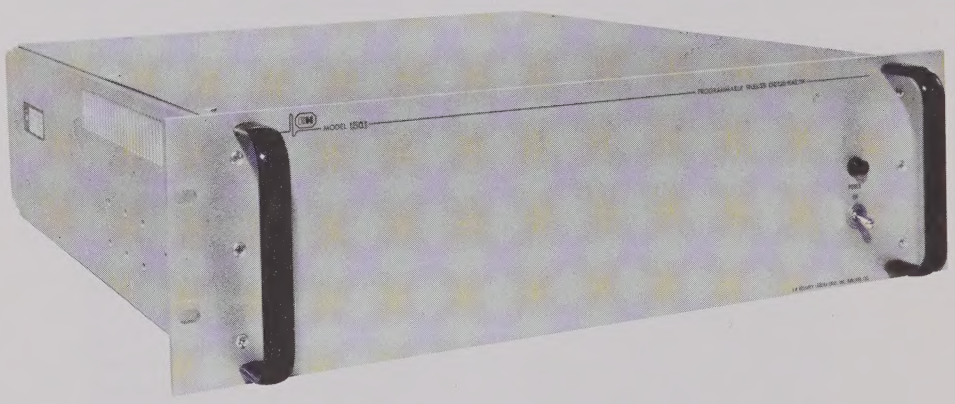


Figure 1-1 Model 1501 Programmable Pulse Generator

SECTION 1
SPECIFICATIONS

1-1 HOW TO USE THIS INSTRUCTION MANUAL

Each section of this manual begins with a general description of the instrument oriented toward the subject matter in that section. Section 1 contains the electrical and mechanical specifications for the instrument. For the operator, Section 2 contains a complete description of controls and procedures. In Section 3, the theory of operation is described.

The schematics are located at the back of the manual. Section 6, in which the schematics are located, also contains assembly drawings of the printed circuit boards and other subassemblies. Individual components are identified on these drawings. For purposes of replacement, components and subassemblies are completely described in the parts lists in Section 5.

Section 4 contains maintenance and alignment procedures. It is strongly recommended that the repair technician read Section 3 and become familiar with the location of the various types of information in this manual before attempting any of the procedures in Section 4. Techniques are oriented strongly toward preventive maintenance and include routine visual checks, voltage and signal tests, and general notes on the use of test equipment with this instrument.

1-2 GENERAL INFORMATION

The E-H Model 1501 Programmable Pulse Generator is a compact unit designed to meet the requirements for a fully programmable pulse generator in high-speed, automatic test system applications. Programmable 10 V output amplitude, and 50 MHz repetition frequency capabilities make the Model 1501 an ideal choice for any application requiring TTL and DTL drive sources.

Full control of all pulse parameters is provided by coarse and fine programming through parallel programming lines. Interface to integrated circuits and adaptation to current logic levels is enhanced by the addition of variable baseline offset and polarity inversion functions, which allow simulation of positive, negative or inverted logic. Baseline offset is inserted after the attenuator to permit full use of the offset capability.

Synchronous and asynchronous gating are provided as useful features for systems applications. Distortion is less than 5% peak–to–peak for all functions.

Normal/inverted and single/double pulse modes are built into the Model 1501. In the inverted mode an extremely high duty cycle can be achieved for the output pulse.

Programming is accomplished through 4 range and mode control lines and 12 control lines for each function. Logic "1" is less than 0.75 V and logic "0" is greater than 2.5 V, with a 5 V maximum. Each program line is equal to one 7400 TTL load. Positive true logic will be supplied on request. Four bits define mode and range information and 12 bits define the 3 digit 1248 BCD coded vernier information.

1-3 SPECIFICATIONS (all specifications assume a 50-ohm resistive load on the output).

a. Pulse Repetition Frequency. From 0.5 Hz to 50 MHz in 8 decade ranges.

b. Pulse Delay. From 10 ns to 10 ms ±3 ns in 6 decade ranges.

c. Pulse Width. From 10 ns to 10 ms in 6 decade ranges.

d. Jitter. Less than 0.1% of setting applies to frequency, delay, or width jitter.

e. Duty Factor. Greater than 50% applies to either delay or width circuit.

f. Modes. Normal/Inverted and Single/Double Pulse. The inverted mode allows an extremely high duty cycle for the output pulse.

g. External Drive. Input drive signal must go from less than 0.75 V to greater than 1.5 V into 1 kilohm. Maximum input 5 V. Maximum frequency 50 MHz.

h. Synchronous Gate. Input drive signal must go from less than 0.75 V to greater than 1.5 V into a 1 kilohm load. Both gate on and gate off modes are under program control.

i. Asynchronous Gate. Input drive signal must go from greater than 2.5 V to less than 0.75 V into a 50 ohm load. Gate off operation only.

j. Trigger Output. Greater than 3.5 V from 50 ohm source width 10 to 200 ns depending on clock frequency.

k. Minimum Double Pulse Spacing. Less than 12% of width range maximum.

l. Amplitude. ±39 mV to ±10 V into 50 ohms from a 50-ohm source.

m. Offset. Less than ±50 mV to ±5 V into 50 ohms independent of attenuator setting. The maximum output amplitude is restricted to ±10 V for the sum of the pulse and offset amplitudes when driving a 50 ohms load. In the off position offset is less than ±10 mV.

n. Pulse Distortion. Less than 5% peak–to–peak for all amplitudes and for all rise and fall times greater than 3 ns.

o. Rise and Fall Time. Less than 3 ns to 8 ms in 6 decade ranges. Separate rise and fall verniers.

p. Ramp Linearity. Less than ±1.5% above 100 ns. Less than ±5% 10 to 100 ns.

1-4 PROGRAMMING

a. Repeatability. ±1% of a setting.

b. Program Error. ±5% of programmed value for amplitude, frequency, and offset. ±5% ±3 ns for delay, width, rise and fall times.

c. Setting Time. <2.5 ms for attenuator and polarity. <750 μs when going to or from ramp ranges 0 and 1.

d. Digital Control Lines. 4 range and mode control and 12 vernier control lines for each function.

e. Control Voltage. Logic "1" less than 0.75 V logic "0" greater than 2.5 V, 5 V maximum. Each program line is equal to one 7400 TTL load. Positive true logic will be supplied on request.

f. Programming Format. 4 bits define mode and range and 12 bits define vernier information in a 3 digit 1248 BCD format.

g. Analog Control Lines. One for each of the seven functions. Standard on all units for optional analog programming of vernier control.

h. Analog Programming. +0.5 V to +5 V or 1 to 10 kilohm resistance control for a 10:1 vernier range.

1-5 MISCELLANEOUS

a. Dimensions. 5-1/4 in. (13.3 cm) high. 19 in. (48.2 cm) wide. 18-1/2 in. (46.9 cm) deep.

b. Ambient Temperature Operating Range. 0°C to 55°C.

SECTION 2
OPERATING INFORMATION

2-1 GENERAL INFORMATION

This section of the Instruction Manual gives installation procedures, and describes the operating controls and modes of operation.

The Performance Verification Procedure given in Section 4 of this manual serves as a receiving inspection. All of the operating controls are shown on the Block Diagram in Section 3 in relation to the functional elements of the instrument. Specifications from Section 1 which directly affect operation of the instrument are reiterated in this section.

2-2 INITIAL INSPECTION AND INSTALLATION

a. Unpacking. Unpack the instrument and verify that it is intact and as ordered. Ensure that any accessories (as listed at the end of Section 1) that should accompany the instrument are present. Inspect the instrument for any physical damage. If damage of any sort is found, a claim should be filed immediately with the carrier. As soon as possible, the instrument should be given a thorough electrical inspection. The Performance Verification Procedure given in Section 4 is recommended for this purpose. If the instrument fails to operate properly or does not meet specifications, contact an E-H Representative.

NOTE

Unauthorized repair or parts replacement during the warranty period may void the warranty. The warranty and instructions for in-warranty repair of this instrument are given on Page II of this manual, opposite the Table of Contents.

b. Installation. The E-H Model 1501 is supplied in a rack-mount configuration. Power connection and fuse requirements are silk-screened on the rear panel. Input ac power is connected via the three-conductor power cord (supplied) to rear panel connector J101. The POWER switch should be turned OFF (down) prior to plugging in the instrument. The instrument is cooled by an internal fan that operates when the POWER switch is turned ON. The top and bottom covers should remain in place when the instrument is in use to provide proper flow of cooling air.

2-3 DESCRIPTION OF CONTROLS AND CONNECTORS

a. Front Panel Controls. The sole front-panel control is POWER switch S201, which controls primary power to the instrument. Rear-panel fuses are provided.

b. Rear Panel Connectors

(1) Trigger Output. This produces more than 1.75 V peak–to–peak into a 50 ohm load from a nominal 50 ohm source. Its width is greater than 7 ns and less than 210 ns at all settings of the frequency programming. The output is a nominal square wave on range seven and is a pulse of 20 to 200 ns on all other ranges.

(2) External Drive Connector. The input drive signal must go from less than 0.75 V to greater than 1.5 V into 1 kilohm. Maximum input 5 V. Maximum frequency 50 MHz.

(3) Asynchronous Gate In. The input drive signal must go from greater than 2.5 V to less than 0.75 V into a 50 ohm load. Gate off operation only.

(4) Synchronous Gate In. The input drive signal must go from less than 0.75 V to greater than 1.5 V into a 1 kilohm load. Both gate on and gate off modes are under program control.

(5) Pulse Output. ±39 mV to ±10 V into 50 ohms from a 50-ohm source.

2-4 PROGRAMMING INFORMATION

a. General. Model 1501 programming can be divided into three parts: Range, Mode, and Vernier. Range control is coded in a 4-2-1 format (three binary lines); vernier is coded in a three-digit BCD format (8-4-2-1) with a total of 12 lines. Mode control is a single-line on/off format, providing such functions as internal/external clock, normal/inverted operation, etc. All of these control lines have inputs equal to one 7400 series TTL load. All lines are programmed with negative true logic, where logic "one" is equal to 0 V.

b. Vernier. The twelve connections that are used for each of the 7 vernier control functions of the Model 1501 are defined in Table 3. It can be seen that each set is made up of three digits in 8-4-2-1 BCD form. All functions are programmed as a three-digit number determining a particular value within the selected range. Width and delay programming are straightforward; the number programmed is numerically equal to the desired value. For example, if a pulse width of 172 microseconds is required, the vernier program would be 172 (in BCD form). Frequency and amplitude do not follow this format, however, and programming these functions will be detailed in the paragraphs following.

c. Frequency. The basic range of the frequency program is from 0.5 Hz to 5 Hz. Because the end points of the ranges are not even decades, a multiplier must be used to obtain the required program. To determine the program for a given frequency, use the following procedure:

(1) Multiply the required frequency, in Hz, by two to obtain "value".

(2) Find the vernier program by taking the three most significant digits of "value".

(3) Find the range multiplier by taking the first digit of the logarithm (base 10) of "value".

For example, if the required frequency is 1.87 KHz (1870 Hz), value is 374 (first three digits of 1870 x 2). The range multiplier is 3, which is the first digit of the logarithm of 3740.

d. Delay and Width. Delay and width are programmed by selecting the correct range and then using the three most significant digits of the required setting as the vernier program. For example, a width or delay program of 750 would be used to obtain a value of 75 ns.

e. Leading and Trailing Edge Ramps. Since the leading and trailing edge ramps of the Model 1501 are constant slope, rather than constant risetime, a calculation must be made to determine the program for a given combination of amplitude and risetime. The full-scale rise and fall ranges are specified in terms of the 10-90% risetime (or falltime) at 10 V amplitude. If the amplitude is less than 10 V, not taking into account any attenuation which may be programmed, then the following formula should be used to determine the rise and fall program. It should be noted that the same ramp range must be used for both leading and trailing edge.

$$\text{Vernier Program} = \frac{\text{Amplitude x } 0.8}{\text{Required Rise/Falltime}}$$

The vernier program value obtained in the calculation above is a **rate** of rise or fall, either in volt/ns or volt/μs. Use the information in Table 1 to determine the correct ramp range for the programmed rate.

References in Table 3 to "+ramp" and "–ramp" are for leading and trailing edges, respectively, in positive and negative normal modes. In positive and negative inverted modes, the + ramp becomes the trailing edge and the – ramp becomes the leading edge.

f. Amplitude. The amplitude vernier program has a 2:1 range, starting at 5 V amplitude with 000 programmed and ending at 9.99 V amplitude with 999 programmed. To determine the program for a given amplitude, use the following formula:

Vernier Program = [Required Amplitude (volts) x 100] – 500

This program is for the single 5 V to 9.99 V range and does not take into account the attenuation program.

g. Offset. The range of offset programming is from 0 to 5 volts. The vernier program is equal to the required offset value in volts, multiplied by 200. For example, if the required offset is 200 mV, the program is 200 x 0.2, or 040.

h. Programming Connections. Tables 2 and 3 list the required connections to rear-panel programming connectors J106 and J107.

2-5 OPERATING NOTES

The risetime of the Model 1501 output pulse has appreciable frequency components up to 500 MHz. If any of the connectors, cables, or attenuators used do not have flat responses in excess of 500 MHz, degradation of pulse risetime will result. Mismatch effects can also degrade the pulse shape. When possible terminate the output of the 1501 into a 50-ohm pure-resistive load. If the input impedance of the device or system under test is other than 50 ohms, use an impedance matching device to minimize the mismatch effects.

(1) Open Circuit Operation. The maximum output amplitude shall be greater than ±19.5 V peak–to–peak as measured into a load resistance >5K ohms. The maximum absolute voltage level from ground shall be limited to 14 volts at minimum offset, 1.5 times the offset voltage is subtracted from the 14 V limit for offsets of the same sign as the output pulse, and the value of the offset is added to the 14 V limit for offset of opposite polarity.

2-6 234 VOLT OPERATION

a. General. The Model 1501 power transformer primary is normally connected for 117 V service. For use with 234 V service, the primary must be reconnected. This is accomplished by altering the input connections and jumpers on the ac input terminal strip, TS101. Proper connections for either type of service are shown on Schematic 5 in Section 6.

b. Reconnection Procedure

(1) Check the rear panel "Power Data" chart to determine the existing power connection.

(2) Disconnect the power cord and remove the bottom cover using the procedure given in Section 4-4.

(3) Locate TS101 on the bottom chassis layout drawing in Section 6.

(4) Remove the terminal strip cover and position the jumpers, as shown on the power supply schematic, for the type of service desired.

(5) Replace the bottom cover on the instrument. Note the change in power connection on the rear panel "Power Data" chart. Change the line fuse, F101, to correspond with the power connection.

Table 1. Range Values

Function	BCD Value	Range
Frequency	0	0.5 Hz-5 Hz
	1	5 Hz-50 Hz
	2	50 Hz-500 Hz
	3	500 Hz-5 kHz
	4	5 kHz-50 kHz
	5	50 kHz-500 kHz
	6	500 kHz-5 MHz
	7	5 MHz-50 MHz
Delay/Width	0	10 ns-100 ns
	1	100 ns-1 μs
	2	1 μs-10 μs
	3	10 μs-100 μs
	4	100 μs-1 ms
	5	1 ms-10 ms
Ramp Rate	0	uncalibrated range*
	1	1 V/ns-100 V/μs
	2	100 V/μs-10 V/μs
	3	10 V/μs-1 V/μs
	4	1 V/μs-0.1 V/μs
	5	0.1 V/μs-10 V/ms
Attenuation	0	x 128
	1	x 64
	2	x 32
	3	x 16
	4	x 8
	5	x 4
	6	x 2
	7	x 1

*The uncalibrated range gives minimum risetime (approx. 3 ns) when 999 vernier is programmed and approx. 30 ns when 100 vernier is programmed. Intermediate vernier programs will give values between 3 ns and 30 ns, but programming is non-linear.

Table 2. Range Programming

BCD	Frequency J106	Delay J106	Width J106	Ramp J107	Atten. J107
4	46	50	54	58	62
2	45	49	53	57	60
1	44	48	52	56	59

Mode	
Ext. Clock	J106-47
Dbl. Pulse	J106-51
Inverted Pulse	J106-55
Gate On	J107-66
Pos. Polarity	J107-63
+ Offset	J107-64
– Offset	J107-65
Logic Ground	J106-56, J106-57, J107-70, J107-71

Table 3. Vernier Programming

BCD	Freq. J106	Delay J106	Width J106	+Ramp J107	−Ramp J107	Ampl. J107	Offset J107
800	1	16	30	1	16	30	43
400	2	17	31	2	17	31	44
200	3	18	32	3	18	32	45
100	4	20	33	4	20	33	46
80	5	21	34	5	21	34	47
40	7	22	35	7	22	35	48
20	8	23	36	8	23	36	49
10	10	24	37	10	24	37	50
8	11	25	38	11	25	38	51
4	12	26	39	12	26	39	52
2	13	27	40	13	27	40	53
1	14	28	41	14	28	41	54
Gnd.	15	29	42	15	29	42	55

Logic Ground J106-15, J106-29, J106-42, J107-15, J107-29, J107-42, J107-55

Signal Inputs and Outputs (All connectors type BNC)

Trigger Output	J102	Sync. Gate In	J105
Ext. Clock In	J103	Pulse Output	J 108
Async. Gate In	J 104		

SECTION 3
THEORY OF OPERATION

3-1 GENERAL INFORMATION

The following section of this manual contains an electrical description of each of the circuits of the E-H Model 1501 Programmable Pulse Generator. The description is divided into two parts. The first part is a discussion of the block diagram for the instrument, and the second part is a detailed discussion of each of the circuits which comprise this instrument.

3-2 BLOCK DIAGRAM (Refer to Figure Number 3-1)

The E-H Model 1501 Pulse Generator is basically identical to any conventional laboratory pulse generator with the addition of appropriate digital or analog programming circuits. The clock multivibrator, which determines the base repetition frequency for the instrument, operates in the frequency range of 5 to 50 MHz. The actual operating frequency is determined by the signal which is supplied by the digital-to-analog converter or by an external analog program level. All of the remaining clock ranges are generated by dividing the 5 to 50 MHz frequency range by an appropriate value in the divide by 10^n counter. For example, the 0.5 hertz to 5 hertz range is obtained by dividing the basic clock frequency range by 10^7. The output of the divider is supplied to the input of a buffer amplifier to drive the width and delay circuits and to a trigger driving amplifier which supplies the trigger output pulse from the Model 1501.

Also associated with the basic clock multivibrator is the synchronous gating circuitry. These circuits provide for synchronously gating the clock on or gating the clock off from a positive going gate signal selected by program control. In cases where external drive is preferred, program control can substitute the output of the external input circuit for the clock circuit.

A second gating circuit is supplied at the input of the delay and width module. This gate is of the asynchronous type.

The delay one-shot operates in decade ranges from 10 nanoseconds down to 10 milliseconds. The absolute delay within any given range is determined by the setting of the D to A converter or external analog program. The ranges are determined by the data supplied to the buffer card whose output causes an appropriate range capacitor and charging current to be selected for each of the six ranges. The delay one-shot's output drives through a set of gates the width one-shot which has identical ranges and operates in the same manner as the delay one-shot.

These gates provide for double pulse operation by supplying both the normal and inverted output of the delay multivibrator to the input of the width multivibrator. This causes the width one-shot to trigger on both the leading and trailing edges of the delay one-shot. The output of the width one-shot is amplified and/or inverted by the pulse logic circuit under program control. When the output pulse is to be complemented, the circuit simply inverts the output of the width one-shot providing the appropriate drive form for the output. In the output module the signal is first shaped and amplified and then presented to the input of the ramp generator.

The ramp generator provides five calibrated and one uncalibrated ranges of ramp speed. Each range controls both the leading and trailing ramp rate. However, there are individual D to A cards for the leading and trailing edges of the ramp signal. The output of the ramp drives a quasi-linear amplifier that supplies the needed amplification and also provides the necessary amplitude control. This amplifier drives the junction of a polarity switch and the back match.

The polarity switch consists of a balun and relay combination which drives the output attenuator. This, in turn, supplies attenuation values of unity transfer for an attenuation ratio of 128 to 1 in binary steps under program control. At the output of the attenuator the offset signal, which is derived from the setting of the D to A converter card or from an external program source, is combined with the pulse generator's output in a current summing technique. The resulting output pulse is supplied to the rear panel of the Model 1501 as the output signal.

3-3 CIRCUIT DESCRIPTION

a. General. Each of the functional blocks of the block diagram is described in detail in the following paragraphs. The following definitions are utilized in this discussion.

(1) Vernier Input. A vernier input is a signal which is either a voltage in the range of 0 to 5 Volts, or a signal resulting from connecting a resistor of 0 to 10,000 ohms to the input in question. All vernier inputs are directly proportional to the parameter they control.

(2) Range Input. The range input consists of three digital control lines which are programmed in octal fashion.

(3) Functional Input. A functional input is a single binary line that controls such parameters as positive or negative output pulse, single or double pulse mode, etc.

(4) Logical 1. A logical 1 is the signal level between 0 and 0.5 Volts.

(5) Logical 0. A logical 0 is a signal level between 2.5 and 5 Volts.

b. Type B Clock Module (Refer to schematic 19978). The basic clock multivibrator is composed of transistors Q4 and Q5 and their associated circuitry. This multivibrator is of the conventional emitter coupled form whose collector resistor has been replaced by clamping diodes CR21, CR22, CR23, and CR24 and current source transistors Q23 and Q24. The charging current for the timing capacitor C4 is supplied by the current source, Q2 and Q3. These transistors are programmed through an input buffer amplifier with transistors Q11 through Q13 providing the vernier control of the clock frequency. Since the capacitor charging current relates directly with frequency, this clock programs frequency directly. The current supplied to the timing capacitor has approximately a 10 to 1 variation from roughly 2 or 2-1/2 mils to 20 or 25 milliamps. In order to cover this range and maintain proper circuit action, the current sources in the collector of the multivibrator must track the timing current sources. This is accomplished via transistor Q1 which, through emitter follower Q25, drives the collector current sources, which supply the appropriate bias currents to the collector of the multivibrator, transistors Q4 and Q5.

Diodes CR21 and CR24 clamp the collectors to a maximum negative excursion of approximately −400 millivolts while diodes CR22 and CR23 provide a positive clamp that is roughly +600 millivolts, thus allowing a 1 Volt collector swing on the clock multivibrator. The reference voltage supply for this positive clamp is controlled by potentiometer R68 which functions as an overall range adjusting potentiometer. Transistor Q26 shifts the bias point of the voltage source for diodes CR22 and CR23 to compensate for the changes in the clamp diodes due to changing operating points. The magnitude of this correction is controlled by potentiometer R53. Potentiometer R26 provides compensation for general circuit non-linearities that occur near the low frequency end of the vernier range.

The output of the clock, which is taken from buffer transistors Q9 and Q10, drives the count down amplifier Q14, Q15, and Q18, and the buss driver Q29 and Q30. The output of the count down amplifier drives a series of decade counters (ICs 1 through 7) which divide the basic clock frequency by any power of 10 from 0 through 7. The operation of this circuit can be described by a simple example. Assume that we wish to be in the frequency range of 50 to 500 kilohertz. Hence, we wish to divide the basic clock frequency by 100. To do this the range input is decoded by IC8 (a one of 8 decoder) to produce a logical 1 on pin 12 and logical zeros on all other outputs. The logical 0 high level at pin 10 provides a logical 0 at pin 12 of IC12. This allows the first decade to run. The logical 0 at the output of IC12 pin 12 and the logical 0 from pin 11 of the IC8 produce a logical 1 state at pin 11 of IC11 which permits the second decade to count (these two decades require opposite preset signals). The logical 1 at pin 11 of IC11 provides a logical 0 at pin 8. The logical 1 from pin 12 of IC8 forces pin 3 of IC11 to go to the logical 0 state. This in turn presets IC5 The 0 state at this point provides a logical 0 at its output which presets IC4 to the count of 9. This action propagates down the chain presetting counters 3, 2 and 1 to the count of 9. Whenever IC6 reaches the count of 9, the buss connected to the base of transistor Q20 moves positive supplying the logical 0 to pin 11 of IC12. When IC7 reaches the count of 9, lines 9 and 10 go to a logical 0 state which provides a logical 0 from pin 8 of IC12. This output pulse, which is 1 clock cycle long, is supplied to the buss driving amplifier, Q35 and Q36. Since we are in fact counting down, current switch transistor Q37 is turned on and transistor Q38 is turned off, as is transistor Q40. So the only amplifier on the buss is the one driven from the count down. This in turn supplies the signal for the output of the board via transistors Q45 and Q46 and to the external trigger amplifier, Q41, Q42, Q47, Q48, and Q49.

The board's output amplifier drives twin 93 ohm coaxial cables in a differential mode to supply drive to the input of the width and delay module. The trigger output amplifier which consists of two current mode amplifier stages and an emitter follower, Q49, is intended to drive a 50 ohm load. However, this circuit is series back matched and will drive any arbitrary external impedance. When a gating signal is to be applied to the internal clock, a positive level is supplied to the base of transistor Q19 via the protective diode bridge, CR1 through CR4. Q19 functions as a buffer stage to drive IC13 and IC14 which function to provide inversion of the input signal under the control of the gate ON OFF functional input. In the gate OFF mode, the output of IC13, pin 6, is at a logical 0 state. This condition allows the decade divider to operate and bias transistor Q21 ON while cutting off transistor Q22. In this condition the base of transistor Q6 will bias one diode drop positive with respect to the bias voltage of transistors Q2 and Q3, hence transistor Q4 will not conduct. When a positive signal is applied to the gate input, transistor Q21 is turned off, Q22 turns on, biasing Q4 to a voltage 1 diode drop negative with respect to the base of Q3. This in turn robs the emitter current from transistor Q3 and conducts it to ground via the collector of Q4. This disables the clock and places it in a condition ready to start the next cycle.

The applied gating signal also causes the preset counter (via a logical 1 at pin 2 of IC12) to preset the decade divider to a count of 899999 so that the first clock pulse will cause IC Q7 to produce an output signal and hence to produce the appropriate drive for the width and delay board in response to the removal of the gate OFF signal. Of course if the functional control line is in the gate ON mode, exactly the opposite operation occurs. That is, the clock is normally disabled and the counter is normally preset to 899999, and when a positive signal is applied to the gating input, the clock turns on and a count down goes into normal operation.

The external drive signal is applied to transistors Q31 and Q32 through the protective diode bridge CR25, CR26, CR27 and CR28 and coupling zener CR29A. These transistors form a Schmidt trigger that shapes the input signal and drives the buss amplifier, Q33 and Q34. In the external mode, current is supplied to the emitter of transistors Q33 and Q34 via transistor Q40 while transistors Q38 and Q37 are disabled.

c. Width and Delay Module (Refer to schematic number 18962). The input signal to the width and delay module is supplied to the bases of current mode gating stage Q22, Q23, and Q24 via zener diodes CR4 and CR5. When a gating signal is applied to the gate input, the flip-flop, which is made up of two of the gates of IC3, toggles on the clock pulse so as to provide a coherent gate signal to the gating transistor Q24. Q24 is biased to remove current from the emitters of Q22 and Q23 and disables the stage. When the input signal returns to ground, Q24 is returned to a normal high state and cuts off. The current is then rerouted to the current mode amplifier, Q22 and Q23. The output of this stage drives

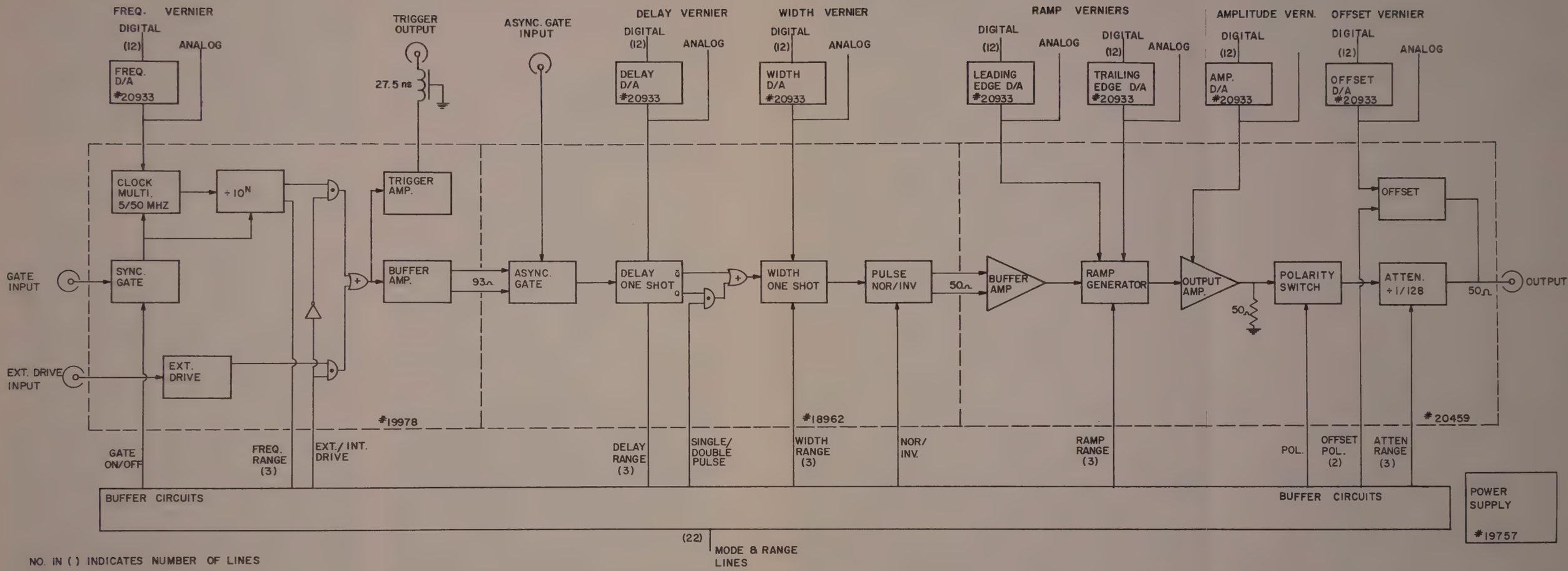


Figure 3-1 Block Diagram

coaxial clipping lines to provide a narrow 5 nanosecond spike on each transition of the input signal. The positive pulse from transistor Q23 and the negative pulse from transistor Q22 are used to drive the delay one-shot. In order to maintain proper circuit and clipping line action the unused pulses from these collectors are terminated in resistors R74 and R75.

The delay one-shot consists of transistors Q25, Q26, and Q27 and their associated circuitry. This multivibrator operates in the following fashion. Normally transistors Q27 and Q26 are on and transistor Q25 is off. The collector potential of Q27 is determined by the negative clamp diode, CR3. When the gating amplifier provides a trigger pulse to the one-shot transistor, Q25 turns on and Q26 and Q27 are turned off. The collector potential of Q27 then rises to the positive clamp potential set by CR2.

The emitter of transistor Q26 is provided with a capacitance to ground and with a positive current source. This current source charges the emitter of this transistor in a positive direction until transistor Q26 begins to turn on. This action again turns transistor Q27 on and regeneratively drives transistor Q26 so that the timing capacitor in the emitter of Q26 is rapidly discharged through the base clamping diode CR13. Once the timing capacitor is recharged the one-shot is back in its normal rest condition ready to be triggered again.

The delay vernier control provides the reference voltage for positive clamp CR2 via the transistor buffer amplifier chain Q17, Q18, and Q19. Varying this bias voltage to the positive clamp diode determines the change in voltage of the timing capacitors and hence the period of the one-shot. Since we are programming the change in voltage to a capacitor, we are in effect directly controlling the period of the one-shot. The 6 ranges of this one-shot are provided by capacitors C8, C25, and C27 and by varying the charging current to the timing capacitors as supplied by the current source transistor, Q10.

The ranging circuit operates in the following manner. A range input is supplied to the 1 of 8 decoder, IC2, which in turn activates the transistor switches to turn on the appropriate timing capacitors and controls the current source for the timing capacitors. In the shortest delay range, none of the programmable timing capacitors are activated. Hence, C8 is the only timing capacitor in the circuit while transistor Q7 is saturated. Approximately 10 milliamps of charging current is available to the timing capacitor during this time. In the next lower range, 100 nanoseconds to 1 microsecond, pin 2 of IC2 goes to a logical 1 state which turns on transistors Q57 and Q55 and switching transistor Q56, which connects the timing capacitor, C27, to ground. On the next range down pin 2 goes to a logical 0 and pin 3 becomes a logical 1. This in turn saturates switching transistor Q42 which connects timing capacitor, C25, to ground. In the 10 microsecond to 100 microsecond range, the next range down, pin 4 becomes a logical 1 with all other pins at logical 0, which again activates switching transistor Q42, thus connecting capacitor C25 to ground and also supplies a logic 1 to the input of IC1 producing a logic 0 at the output pin 3 of IC1. This high logic level causes transistor Q7 to be cut off reducing the timing current by a factor of 10. Transistor Q28 is also cut off, reducing the bias current to the one-shot. This causes an approximate decade step in the time required to charge capacitor C25. The error term generated is due to the change in bias current to the timing transistor. This is corrected by the current supply to R137, and to the base of transistor Q20, the bias source for the negative clamp. The 100 microsecond to 1 millisecond range is generated when the input causes pin 13 to become a logical 1. With this input low, timing capacitor C26 is activated, and the charging current is returned to 10 milliamps. In the lowest range, the 1 millisecond to 10 millisecond range, the logic 1 is on pin 12 of IC2, which reduces the charging current to the timing capacitor by a factor of 10 while maintaining capacitor C26 active in the circuit.

(1) Delay Buffer Amplifier. The output of the delay one-shot is coupled via NPN current mode pair Q29 and Q30 to the bases of the current mode pair, Q31 and Q32, whose collectors are differentiated in clipping lines CL3 and CL4 and provide the appropriate drive pulses for the OR gate.

The single pulse/double pulse OR gate always supplies drive pulses to the width one-shot via diodes CR23, CR24, CR38, CR39, and CR40. This pair of signals provides a drive pulse to the width one-shot at the end of each delay interval. In the double pulse mode, diodes CR31, CR32, CR35, CR36, and CR37 also supply pulses to the width one-shot. This OR gate is so designed and controlled that it always provides an approximate 91 ohm terminating resistor for the clipping lines. This provides a 5 ns wide pulse at the input of the OR gate under all operating conditions.

(2) Width One-Shot. The width one-shot consists of transistors Q33, Q34, Q35 and their associated circuitry. This circuit operates in exactly the same fashion as does the delay one-shot and will not be discussed in any further detail.

The output of the width one-shot drives current mode pair Q38 and Q39. As a function of the normal inverted control line (pin C7) either transistor Q36 or Q37 is saturated. The saturated transistor shorts the current mode pair collector to the +5 volt supply eliminating the output signal from this source. The other transistor is cut off and allows the signal from its collector to be coupled to the base of the output buffer Q40 and Q41. This signal is amplified by the buffer stage and drives a balanced 50 ohm transmission line system to the output board. When the normal inverted line is placed in the opposite state, the opposite collector of the current mode pair, Q38 and Q39, is connected to the base of the output drive pair.

d. Type C Output Board (Schematic 140-20459). The input signal for the output board is applied through isolation transformer T1 to the dc restoring flip-flop, Q7 and Q8, through the differentiating capacitor, C1. This circuit is utilized to provide isolation of the output circuit from the timing circuits. The output of the restoring flip-flop drives a two stage current mode amplifier, Q50 and Q51, and Q18 and Q19. This amplifier in turn drives the current switching bridge which consists of transistors Q55 and Q56 for the current source side and transistors Q57 and Q58 for the current sink side. In the final analysis this entire circuitry simply determines whether current source Q11 and Q12 or current sink Q53 and Q54 are connected to the input side of R6. The output of this resistor, R6, provides either a constant current source or a constant current sink for the timing capacitors. The constant current charging and discharging of these timing capacitors provides the necessary linear ramps for the output amplifier section. The input of this amplifier is transistor Q27 which is an emitter follower which drives a current mode pair consisting of driver transistors Q28, Q59 and Q60 and output transistors Q37 and Q62. The input transistors are operated in parallel as are the two output transistors. The output of this amplifier is coupled via a polarity switching relay and a balun to the

input of a pi network attenuator system. The first section of the attenuator is a divide by two network which is either enabled or disabled by relay K2. The second section is a divide by four attenuator which is controlled by relay K3. The final section, a divide by 16 attenuator, is controlled by K4. The output of this attenuator section is coupled directly to the output of the instrument. Also connected to the output of the attenuator is the offset circuit which provides an offset current to the output which is independent of the setting of the attenuator. The output amplifier also drives a 65-ohm resistor and other miscellaneous networks whose cumulative effect is to provide a 50-ohm source impedance for the pulse generator. This source impedance, of course, is provided to minimize the effect of cable reflections and mismatched loads. To illustrate this operation a positive, normal pulse's path will be outlined. When the pulse starts transistor Q7 is turned off. This results in the current sink, Q54, and Q55, being connected via transistor Q58 to the timing capacitor which has been selected. Before the pulse had occurred diode CR30 had clamped the timing capacitor and the emitter follower's base to a potential slightly positive of the −20 V plane. This action completely cuts off the output pair, transistors Q62 and Q37. As the timing capacitor starts to discharge the voltage on the emitter of Q27 moves in a negative direction which allows current to be switched from the driver, transistors Q28, Q59, and Q60, to the output pair and hence on to the polarity control relay. This transfer of current to the output continues until the clamping diode, CR31, catches the bases of the output driver transistors. Shortly after this occurs clamping diode CR29 catches the ramp timing capacitor and also prevents it from continuing in a negative direction. It should be pointed out that the current from current source transistor Q83 in the emitter circuit of the output amplifier is always sufficient to provide some on current for the driver transistors. The output of this amplifier is now coupled through the polarity switch which then selects the direction of input to the balun so that the pulse will be inverted before going to the attenuator. At the end of the pulse the input restoring flip-flop changes state and causes a current source, Q11 and Q12, to be coupled to the timing capacitor instead of the current sink via transistor Q56. This current now charges the timing capacitor in a positive direction. As soon as the timing capacitor has moved sufficiently far so that the emitter follower again starts to draw current, the current in the output pair begins to reduce. This current reduces to zero before the clamping diode, CR30, clamps the positive charging of the timing capacitor. The circuit is now ready to produce the next output pulse when again the restoring flip-flop changes state. The ramp timing capacitors are selected via the three data bits supplied to pins A1, A2, and A3. These signals are coupled via isolating transistors Q68, Q70, and Q72, Q73, Q74 and Q75 to the input of a 1 of a 1 of 10 decoder. The output of this decoder drives transistor switches to pull in the appropriate timing capacitors and or relay. For the fastest ramps no capacitors are pulled in. For the next range down capacitor C43 and C11 are energized via switching transistor Q79. This is accomplished by causing pin 2 of IC1 to go to −35 volts which, in turn, saturates the switching transistor. In the next range relay K6 is activated and none of the capacitor ranges are pulled in. Activating this relay permanently connects capacitor C9 and C10 to the ramp timing buss. On all the remaining ranges one of the transistor switches, Q76 – Q78, is activated which, in turn, also activates the relay and maintains this part of the path in conduction. Whenever a capacitor is not in use its potential is pulled to the −35 volt level via the 1 megohm discharging resistor. Since the output of this board is floating with respect to ground some means must be provided for coupling between the floating supply and the ground reference supply. The input of the timing capacitor range circuit is a basic example of how this is accomplished. If range 1 is activated, transistor Q70 is turned on which pulls a small current from the −35 volt supply and at the same time transistor Q71 is turned on. This supplies a small amount of current to the sensing resistor, R153, which in turn causes a current to be pulled from the VO supply via transistor Q45 to exactly balance the current necessary to couple the digital information to the range select circuitry.

(1) Amplitude Control. Transistor Q1 provides the constant current bias for the amplitude vernier control whose input emitter follower is transistor Q1. This emitter follower drives the grounded base stage, Q3, which provides a gain of 0.5 to the incoming signal voltage and produces the amplitude setting information referenced to the +15 V supply at the collector of Q3. Transistor Q15 is utilized to communicate the amplitude information to the floating output circuitry. This form of analog coupling provides good isolation between the two supplies since the voltage on the base of Q16 never approaches the potential of the base of Q15. Transistors Q16 and Q17 drive emitter follower Q20 to establish the amplitude level of the output circuit. The potential of the emitter Q20 is coupled to a unity gain power driver, Q21 and Q22, which supplies the clamp level for diodes CR29 and CR31, thus controlling the amplitude of the output pulse. The collector of transistor Q20 is coupled to the base network for the output current source driving transistor, Q82. This circuit varies the amount of current supplied to the output stage to minimize distortion and to aid in rising the output voltage transfer function. Also connected to the collector of Q3 are two current source transistors which drive the leading and trailing edge ramp time vernier inputs. When resistance programming is utilized to program the ramp time, the fact that the current source magnitude is proportional to the amplitude provides constant rise time programming.

(2) Leading Edge Vernier. The basic circuitry in this vernier operates in exactly the same manner as the input circuitry and isolation circuitry of the amplitude control. This circuitry is made up of transistors Q46, Q89, Q48, and Q52. However, unlike the amplitude control, the output of Q52 directly controls the current sink, Q53 and Q54. The programmed value of this leading-edge ramp time produces several secondary effects in the circuitry. These effects are minimized and or corrected by sampling the level of sink current that is being supplied to the timing capacitors.

Compensation for the effects of varying the leading edge program is accomplished by the two current source transistors, Q13 and Q14, whose base signal is derived from the output of the leading edge vernier isolation amplifier. Q14 applies a small correction to the amplitude circuit which minimizes the effect of changing the discharge currents and the emitter follower currents in the output amplifier chain. Transistor Q13 provides an edge balance and corrects the trailing edge vernier control so there is little or no effect due to leading edge programming. The primary need for correction arises from the finite beta of the emitter follower and, hence, its change of base current with the change of emitter current.

(3) Vernier Trailing Edge Programming. The vernier trailing edge programming circuitry is essentially identical to the leading edge vernier except it is not necessary to provide any compensation networks for this function. The amplifier transistor chain consists of Q4, Q88, Q5, Q6, Q9, and Q10, whose collector is the output of the isolation amplifier and which drives Q11 and Q12, the trailing edge current source.

(4) Offset Circuitry. When a logic 1 is applied to one of the offset polarity inputs IC3 decodes the condition and turns either Q24 or Q25 off. For any condition in which both of the inputs are either a logic 1 or a logic 0, both Q24 and Q25 are left on. The output of these two transistors control saturate current switches, Q36 and Q39, which disable the offset amplifier when their associated transistor is conducting. The offset vernier control is coupled via Q31 to the base of Q33 which acts as a level shifting transistor. R94, the offset range control, and the emitter Q33 provide the full scale adjustment for the offset circuitry. The collector of Q33 drives complementary emitter followers Q34 and Q35. These supply the appropriate signal to the current source, transistors Q41 and Q42, for the positive offset current. This offset current is coupled to the output via the inductor chain L14 and L15. When negative offset is programmed the signal from the collector of Q32 drives the emitter follower Q38 which again supplies the appropriate signal to the negative current source, transistors Q40 and Q43. These transistors supply the negative offset current for the output.

e. **Digital Buffer Circuit** (Refer to schematic number 20930). It is quite plain that the buffer board consists primarily of a set of ICs to isolate the incoming digital signals from the remaining circuitry of the instrument. ICs 8 through 14 are inverters if negative true logic is driving the instrument. For positive true logic, buffer amplifiers are substituted for these ICs. In either case the output of the first buffer amplifier drives an inverting gate which supplies the drive for the internal circuitry of the Model 1501. Each one of the range and mode control lines pass through one of the buffer chains before being utilized to program the Model 1501. The transistors Q1, Q2, and Q3 provide a means for storing a single range program on the buffer card. If the external program control lines (card A, pin B) is set at a logical 0 state, transistor Q3 will be saturated causing all of the outputs of ICs 1 through 7 to go to a logical 0 state and provide a 0 reference signal on the programming buss. In order to implement this programming, hot carrier diodes are placed between each of the logic 1 mode and control lines and the programming buss. This supplies the necessary logical 1s to the range and mode inputs. (See Table 2-1 for programming details.)

f. **Power Supply** (Refer to schematic number 19757). The E-H Model 1501 utilizes four nearly identical power supplies to supply the analog circuitry, and a fifth supply is utilized to deliver the voltage necessary for the logic circuitry. This supply utilizes a fixed reference IC (IC301 which is located on the chassis) and an over voltage and reverse polarity protection circuit which consists of CR1, CR2, and CR3. The IC regulator is so designed that it automatically protects itself against short circuits. However, if an over-voltage condition exists the SCR CR2 is turned on via zener diode CR1 and its gate circuit, and effectively crow bars the power supply to ground. If for any reason the supply is shorted to the −15 V supply, diode CR3 clamps the supply to −0.7 V. In either case the digital ICs within the instrument should be protected.

The remaining power supplies in the box are similar to the +15 V supply which consists of IC1, Q304, and the associated circuitry. The output voltage of this supply is sensed by input pin 6 of IC1 at the junction of the voltage divider made up of R1 and the parallel combination of R6 and R7. The magnitude of the voltage at pin 6 with respect to ground is approximately 4 volts. This input produces a controlled signal at pin 3 of the IC which drives the base of the series pass transistor, Q304, whose emitter supplies the current for the +15 V supply. Before this current is passed to the supply buss, however, its magnitude is monitored via resistor R8. If the current through this resistor exceeds about 1-1/2 amps, pin 5 of the IC is moved in a negative direction which cuts off the output of IC1, turning off the series pass transistor and limiting the overall current of the supply. A secondary protection loop exists utilizing the internal current sensing capability of this IC via the feed back to pin 4. If the base current of Q304 exceeds 100 mA again, IC1 current limits and shuts down the supply. This supply is set within 1% of its nominal value at the factory and should remain within 1%.

g. **Parallel D/A Converter** (Schematic 140-20933). All of the D/A converter cards utilized in the Model 1501 are identical with the exception of a jumper wire which determines the specific function which the D/A card will perform. For example, if the card is to be an amplitude D/A card a jumper is placed between the hole marked A and the hole that is connected to pins J and 8 on the connector. Thus when the card is inserted into the instrument it connects the output of the D/A converter to the appropriate vernier functional control line. The operation of this D/A converter is conventional. A negative true input is applied to ICs 1 through 3. The output of these ICs control the transistor switches, Q2 through Q15, which directly program the weighted resistor network. The weighted resistor network, R11 through R22, provides a BCD1248 coded input to the summing junction for operational amplifier IC4. If a 000 count is programmed none of the transistors are turned on and there is no current flowing through any of the resistors. As a result the current through resistors R3 and R4 is balanced against the current flowing in R9. The current in R9 is proportional to the voltage difference between the output of the operational amplifier and the inverting input. The voltage of the inverting input will be exactly the same as the voltage of the non-inverting input when the system reaches equilibrium. Thus, if a proper current is supplied via R3 the output voltage of the operational amplifier will have to be exactly 0 volts when none of the resistors in the weighted ladder network are activated. When a resistor is connected to ground via the switching transistor, it reduces the total amount of current flowing towards the negative input of the operational amplifier and hence causes less current to flow through R9. This means the output voltage of IC4 must raise to exactly compensate for the resistor which has been connected to ground. The output voltage from the card is directly proportional to the digital input control.

SECTION 4
MAINTENANCE

4-1 GENERAL INFORMATION

This section of the manual gives maintenance notes and alignment procedures for the E-H Model 1501. The instrument requires a minimum amount of maintenance; however, normal aging of electronic components may eventually cause abnormal operation. Use of the following procedures should forestall many minor malfunctions, or permit their detection before a major repair is required.

4-2 PREVENTIVE MAINTENANCE

a. **Cleaning and Visual Inspection.** A regular program of inspection and maintenance is recommended to minimize down-time. The operating environment and amount of usage will dictate how often the instrument should be cleaned; in the absence of more stringent conditions, inspection every four to six months is recommended. Check the instrument in the following manner:

(1) Disconnect the power cord. Inspect the exterior of the instrument for broken knobs, switches, or connectors.

(2) Remove the top and bottom covers using the disassembly procedure in Subsection 4-4. If the internal surfaces and components have an excessive amount of dust deposited on them, use a low-pressure stream of air and a soft brush to remove the foreign material.

CAUTION

Do not clean the printed circuit boards with solvents, since damage to the circuits may result.

(3) Check the physical integrity of components and wiring. Look for evidence of loose connections, broken terminals, leakage of insulation compounds, and heat damage. In most cases, the source of a visually detected trouble is easily located. In the case of heat damage however, care should be taken to locate the original cause of the overheating before the instrument is put back in service.

4-3 PERFORMANCE VERIFICATION PROCEDURE

The following procedure serves as both receiving inspection and a check of the instrument's specifications. In the former sense, this check should be performed as soon as possible after receipt of the instrument. In the latter sense, the procedure can be used to verify the effectiveness of repairs or alignment.

a. **Recommended Test Equipment.** The following is a list of the test equipment recommended for verifying proper operation of the E-H Model 1501 Programmable Pulse Generator.

(1) Oscilloscope. A fast rise-time oscilloscope having an effective passband sufficient for accurate observation of 2 ns rise-time pulses. Two vertical channels plus dc offset capability is also necessary to make the correct measurements.

(2) A general purpose oscilloscope with dc to 25 MHz passband.

(3) A digital voltmeter.

(4) A pulse generator having a repetition frequency to 50 MHz and a variable output to at least 2 V into 50 ohms.

(5) Several lengths of good quality 50-ohm coaxial cable and a high-quality 10:1 rF attenuator.

CAUTION

The full unattenuated output of the Model 1501 is capable of permanently damaging the input of a sampling oscilloscope. In the X1 and X2 attenuator positions the Model 1501 can deliver output pulses greater than 1 V. When using these positions be sure there is enough attenuation in the signal line to protect the scope. The trigger output of 2 V can also damage the oscilloscope's trigger input.

b. Clock Check-out. With the clock programmed for internal range 7, gated off mode, determine that the vernier will change the frequency from less than 6 MHz to over 50 MHz. Change the range to range ϕ and determine that a frequency of more than 0.4 Hz but not over 8 Hz can be set at the maximum frequency end of the vernier. The frequency should be monitored at the trigger output.

Next set the frequency of the clock to about 50 MHz and apply an external gate signal of 1.5 to 1.7 V positive amplitude from a base line of 0 to +0.3 V. Synchronize the scope from the generator which is being used to gate the Model 1501 clock. By adjusting the pulse width of the gate pulse generator it should be possible to gate one pulse out of the pulse chain in the gate off mode and gate one pulse on in the gate on mode. Repeat the above test at 2.5 MHz and also check for proper operation in the higher frequencies in both modes. Set the drive pulse generator to 50 MHz and determine that the external drive circuit has no effect until

the external drive mode is programmed. The output of the clock should follow the drive pulser to at least 60 MHz when the external mode is selected.

c. Delay and Width Card. Program the delay to approximately 50 ns and the width to 20 ns with any convenient clock frequency that produces less than 25% duty factor. Put the instrument in the double pulse mode and check the signal at the output connector. Check for correct operation of the inverting control. Then connect the gate input to +2.5 V and determine that the scope pattern scales by a factor of approximately ten for each step. Frequency is to be kept low enough so that the duty factor will be less than 25%.

d. Output Board. Make the following setup and monitor the output of the pulse generator with a sampling scope.

FREQUENCY	3 MHz
DELAY	as needed
WIDTH	50 ns
RISE/FALL TIME	min
OFFSET	set to off and zero
AMPLITUDE	7.5 V
SINGLE/DOUBLE	single
NORMAL/INVERTED	normal
POSITIVE/NEGATIVE	positive

The rise and fall times should be less than 5 ns. Step through the attenuator control and see that the output reduces by a factor of two for each range.

With a pulse amplitude of less than 1 V peak–to–peak determine that offsets of ±5 V ±5% can be set. Turn the offset off.

Program for an output of −10 V and the pulse width to 150 ns. Check that range 1 (minimum rise and fall) is 8 ns and maximum is 80 ns. Set the leading and trailing edges to a rise time of 30 ns. Determine that all ranges of the ramp are operating by stepping through each one. Frequency and width will have to be altered to make a visible presentation.

This completes the performance verification procedure.

4-4 RECALIBRATION PROCEDURE

a. General. The recalibration procedure should be performed following component replacement and at any time when failure to meet specifications is not traceable to component failure. Prior to performing the recalibration procedure, read Section 3 of this manual. A thorough understanding of operating principles is necessary to obtain optimum performance from the instrument.

b. Disassembly Procedure

WARNING

AC POWER DISTRIBUTION TERMINALS HAVE PROTECTION DEVICES OVER THEM SO THAT THEY ARE NOT EXPOSED. BUT ANYTIME THE INSTRUMENT IS PLUGGED INTO THE AC LINE IT IS POTENTIALLY DANGEROUS WITH THE COVERS OFF AND THE INSTRUMENT CONNECTED TO THE AC POWER SOURCE. CAUTION IS RECOMMENDED TO AVOID INJURY TO PERSONNEL.

Before disassembly, turn OFF the POWER switch and disconnect the three-conductor power cord. The top cover can be removed by removing the eight screws on its periphery. The bottom cover can be removed in a similar manner. All of the screws mate with captive fasteners.

c. Recommended Test Equipment. The same equipment as used in the verification procedure may be used in the calibration procedure.

d. Power Supply Calibration (Assembly Number 401-19756). The output of the +15 V supply should be adjusted to +15 ±0.15 V with a nominal 117 V line connected to the instrument and a 1 amp load connected to the 15 V supply. The supply is calibrated by selecting a value for R6 which allows the output to follow within the predetermined limits. The nominal value of this resistor is 47 Kohm. Next, the −15 V supply is adjusted to provide −15 ±0.15 V when loaded with a 1 amp load and when the power supply is operated at normal line voltage. Resistor R12 is selected to adjust the supply within limits, and its nominal value is also 47 Kohm.

This completes the alignment procedure for the Model 1501 power supply. However, a measurement should be made of the +5 V supply to determine that it is within normal operating limits of +5 ±0.5 V when loaded with a 1 amp load and when the power supply is operating at nominal input of 117 V.

e. Parallel D to A Converter (Assembly Number 401-20932). Before attempting to calibrate this card, determine that the +15 V supply is within ±0.15 V of the specified value.

(1) Program in 000 and adjust R30 minimum adjustment to produce less than 1 mV at the output of the card.

(2) Program in 999 and adjust R6, the full scale adjustment, to produce an output voltage of 4.995 ±1 mV.

(3) Repeat (1) and (2) until no further adjustment is necessary to meet the specifications at the high and low limit programmed values.

(4) Program in a value of 799 and record the output voltage to the nearest mV. Now program in an 800 count and again measure the output voltage. This value should be within the range of −0 +0.15% of the value measured at 799 count. This concludes the calibration of the D to A card.

f. Type B Clock Board (Assembly Number 401-19977). Three points will be utilized to calibrate the frequency vernier. 5 MHz is the maximum frequency on the range to be used and corresponds to an analog program voltage of a 5 V or a digital program value of 1000 count. Mid-scale is a frequency of 2 MHz, an analog value of 2 V or a digital value of 400 count. Finally a min value corresponds to 500 KHz and has an analog value (program value) of 0.5 V and a digital program value of 100 count. With normal supply voltages presented to the clock and the range 6 selected, the following procedure is to be followed.

(1) Program the clock to mid frequency and adjust R68, the range adjust, to provide an output frequency of 2 MHz.

(2) Change the program value to 1000 count maximum frequency and adjust R53 high frequency adjust so that the clock produces a frequency of 5 MHz.

(3) Program the clock to minimum frequency and adjust R26, the low frequency adjust, to a frequency of exactly 500 KHz.

(4) Repeat the above steps until the error on all of the steps without adjustment is reduced to less than ±2% of the programmed value. The frequency should be measured with a counter whose input is connected to the output of the trigger circuit.

The time base accuracy of the counter should be better than 1 part in 10^6. Since there is no other analog control in the clock circuit for other ranges, no further adjustment is necessary. However, the clock should be checked to determine that it will operate as a whole over the entire frequency range and that each of the decade ranges is approximately correct in frequency.

g. Width and Delay Module (Assembly Number 401-18961). Before attempting to calibrate this board, determine that the ±15 V supply is within ±15 mV of the nominal value. In order to attain the specified absolute accuracy for the width and delay board, it is necessary to measure all time intervals to within an accuracy of at least ±0.5% of programmed value ±0.5 ns. In any case, no alignment should be attempted unless the equipment on which the alignment is to be done is accurate to within ±3% of measured value ±0.5 ns. In this case, of course, the absolute accuracy of the delay and width card may not meet specification, but it will probably provide sufficient absolute accuracy for most practical applications and will be aligned accurately enough so that proper operation of the card will be insured. The following set-up should be provided for the card prior to the start of alignment: a repetition frequency of 20 KHz, a delay program value of 50 ns, control settings of single pulse, normal pulse, and range 2 for the width one-shot. All time measurements should be made on the output. The output should be in its fastest rise time and fall time condition. All measurements are to be made with the output loaded with 50 ±0.25% load.

(1) Program a 1 μs pulse width and adjust R60 minimum adjust for less than a 2% error.

(2) Program in a 10 μs pulse width and adjust R46 full scale adjust for an error of less than 2%.

(3) Repeat Steps 1 and 2 until no further adjustment is necessary.

(4) Program the width to range 3.

(5) Program a pulse width of 10 μs and adjust R179 3/4 min. to produce an error which is less than 2%.

(6) Program on range 3 a 100 μs pulse width and adjust 3/4 maximum adjust, R52, for less than a ±2% error.

(7) Repeat steps (5) and (6) until no further adjustment is necessary.

(8) Program a 50 μs wide pulse and reduce the frequency to 2 KHz, and then determine its error to be less than ±3%. If an error in excess of 3% occurs, adjust R60 minimum adjust and R46 full scale adjust to bring the range within specification. Repeat all preceding steps.

(9) Reduce the repetition rate to 200 Hz and program a 5 ms pulse width. Determine its error to be less than 3%. If the error is greater than 3%, adjust R179 3/5 minimum adjust and R52 3/5 maximum adjust to produce an acceptable setting. Repeat steps (5), (6), and this step until satisfactory results are produced.

(10) With a repetition rate of 2 MHz, program a pulse width of 20 ns. Adjust R185 range 0 minimum adjust for a pulse width of 19 to 20 ns.

(11) The width circuit has been calibrated, and the following set-up should be made to calibrate the delay circuit. Program the width circuit for a pulse width of 500 ns in the normal pulse mode. Change to a double pulse operation, and reduce the repetition rate to 20 KHz.

(12) Repeat steps (1) through (10), except use the period of time between the 50% point of the leading edge of the first pulse and the 50% point of the leading edge of the second pulse as determining the "pulse width", in this case the delay timing.

(13) Repeat, using the same technique as set (11) for the delay circuit after reducing the pulse width to 10 ns. This completes the calibration of the delay and width board.

h. Type C Output Board (Assembly Number 401-20458). Calibration of this board should be done only in a Model 1501 or 1502 main frame which provides the appropriate transformer shielding and all the necessary power supplies and drive signals. Before attempting calibration of the board, the −20 V supply should be adjusted using the potentiometer R201 to −20 V ±0.1 V. The −35 V supply should be adjusted using R204 to −35 V ±0.1 V. This assembly calibration procedure will be broken into three parts: the ramp calibration, the amplitude calibration, and the offset calibration. Any one or all of these calibration procedures can be used at any time. It is not necessary to calibrate the entire board in order to calibrate any one particular function. However, in the case of the ramp calibration it is necessary to determine that the amplitude calibration is correct before proceeding to the ramp calibration.

During the calibration procedures the timing functions, such as repetition rate and pulse width, should be adjusted to give

an appropriate presentation for the measuring instruments. In no case should the duty cycle be allowed to exceed 25%. All measurements in the output should be made into a 50 ohm ±0.1% load of good frequency characteristics.

i. Amplitude Calibration.

(1) Program a positive, normal pulse of amplitude 5 V and measure the voltage across resistor R20 in the emitter of resistor Q4. Record this voltage.

(2) Program the positive, normal amplitude to 10 V, and again measure the voltage across R20. Adjust R7, the amplitude range control, to produce a voltage reading that is equal to the 5 V measured value times 2 ±0.25%. These two voltage levels are nominally 2.5 V for the 5 V amplitude programming and 5 V for the 10 V amplitude programming.

(3) Connect a DVM to the output of the module and gate the clock off. Program the instrument for a negative, inverted pulse of amplitude 5 V. Adjust the potentiometer R65, amplitude minimum, to produce an output voltage of 5.075 to 5.125 V.

(4) Program the amplitude to −10 V in the inverted mode and adjust R55, amplitude maximum, to produce an output voltage of 10.15 to 10.25 V.

(5) Repeat steps (2) and (3) until no further adjustment is necessary.

(6) Check to determine that each of the attenuator steps is within the specified accuracy of ±2%.

j. Offset Calibration. Program the output for a positive, normal 10 V output and gate the clock off.

(1) Program the offset for +5 V, and using a DVM, adjust the offset range potentiometer R94 to produce an offset level of 5 V ±0.05 V.

(2) Program the offset for a −5 V output, and adjust the negative offset potentiometer R104 to produce an output voltage of −5 V ±0.025 V.

(3) Check that the amplitude measured at the output of the Model 1501 is less than ±50 mV with a programmed input of either +0 or −0 V.

(4) With the offset "off" and the positive pulse output programmed, determine that the maximum offset is less than 10 mV.

k. Ramp Calibration. All of the following ramp rate measurements are to be made on a positive pulse between the absolute voltage levels of 0.5 V and 4.5 V. The procedure will call out the total time necessary to traverse this range. The initial conditions for this calibration procedure are as follows: repetition rate is 6 KHz; pulse width is 30 μs; delay is as needed for appropriate presentation of the output pulse; offset is OFF; amplitude is initially set to 5 V on range 7; ramp range is 3 programmed with leading edge program of 1 V per μs and trailing edge program of 5 V per μs.

(1) Adjust ramp minimum, R34, to produce a ramp time of 4 μs ±5%.

(2) Program the amplitude to 5 V on range 6 and the leading ramp rate to 10 V per μs. Adjust R71, ramp 1 maximum, for a ramp time of 0.8 μs ±2%.

(3) Program the leading edge to a ramp rate of 1 V per μs and adjust R35, ramp 1 minimum, to produce a ramp time of 8 μs ±2%.

(4) Program amplitude to 5 V on range 7 and ramp rate of 10 V per μs for the leading edge. Adjust R71, ramp 1 maximum, for 0.4 μs ±2%.

(5) Repeat (1) through (4) until no further adjustment is necessary.

(6) Invert the output pulse and with the output amplitude set at 5 V on range 7, program the trailing edge ramp rate to 1 V per μs. The following measurements are all made on the negative going ramp. Adjust ramp to minimum to produce a 4 μs ±5% ramp time.

(7) Alternately program the leading edge ramp time between 1 V per μs and 10 V per μs, and adjust edge balance R51 until there is no effect on the trailing edge ramp time.

(8) Program the amplitude to 5 V on range 6 and the trailing edge ramp time to 10 V per μs. Adjust ramp 2 maximum, R31, to provide a ramp time of 0.8 μs ±2%.

(9) Program the leading edge ramp time to 5 μs per volt and the trailing edge ramp time to 1 V per μs. Adjust ramp 2 minimum, R25, to produce an 8 μs ±5% ramp time.

(10) Program the amplitude to 5 V on range 7 and the ramp rate to 10 V per μs. Adjust ramp 2 maximum, R31, to produce a ramp time of 4 μs ±2%.

(11) Repeat steps (7), (8), (9), and (10) until no further adjustment is necessary.

(12) Using a positive, normal pulse, program to 5 V on amplitude range 6, 50 V/μs ramp rate for both leading and trailing edges. Adjust capacitor C43 to provide a ramp time of 16 ±1 ns.

(13) Check to determine that all the calibrated ranges, range 1 through 5, provide an accuracy of ±3% as measured with the fastest rate of rise and the fastest rate of fall on a pulse whose amplitude is set at 5 V for range 6. The above completes the calibration procedure for the output board and for the instrument.

4-5 TROUBLE-SHOOTING PROCEDURE

a. General. The information presented in this section is for the expressed purpose of simplifying and speeding the isolation of any fault that may occur within the instrument. Before attempting to do any major maintenance on this instrument the following test equipment should be available.

(1) A digital voltmeter capable of making measurements to an absolute accuracy of less than 0.1%.
(2) A sampling scope with less than 350 p sec. rise time.

(3) Some method of parallel programming the instrument in digital form.
(4) A pulse stimulus to drive the external gate, external drive and asynchronous gate inputs.

b. Preliminary Step. Before attempting any other maintenance on the instrument the power supply voltages should be checked to determine that they are within their specified accuracies of; +15 ±0.15 V, −15 ±0.15 V, +5 ±0.5 V as measured on the test points on the chassis with a power supply voltage between the nominally specified limits. The output of the D/A converters should also be checked. First with a count of 800 on each of the D/A cards thus providing an output voltage of 0 ±5 mV. Assuming these conditions are met, the following outline should help isolate the trouble.

c. No Trigger Output Pulse. For any clock vernier or range setting, if the instrument operates normally in every other respect, the problem is in the trigger output amplifier and transistors Q41, Q42, Q47, Q48, and Q49 should be checked. If there is also no output pulse the problem is in either the clock circuit, Q4 and Q5, and their associated current sources and circuitry, or in the clock buffer amplifier, Q9 and Q10, or Q29 and Q30. A 5K sampling probe should be used to measure the waveform on the collector of Q4. This should be a square wave of approximately 1 V amplitude at the programmed frequency. If the square wave is present the signal should be followed to the amplifier chain until the fault is detected. If it is not present it is necessary to trouble-shoot the circuitry associated with these two transistors.

d. Clock Operates Correctly Only on Range 7. Program range 6 and measure the signal on pin 8 of IC7. This should be a signal of at least 1.5 V amplitude whose base line is less than 0.5 V from ground. If the signal is not present transistor Q14, Q15, and Q18 or their associated circuitry has malfunctioned. If the signal is present check pin 1 for a low measurement. If 1 is not low then either IC12 or IC8 has malfunctioned. If it is low, check pin 8 of IC12 for a pulse whose duty cycle is 20% and whose repetition frequency is 1/10 that of the basic clock frequency. If the signal is present transistors Q35 or Q36 has failed. If the signal is not present and pin 11 is in the high state, IC12 or IC7 has failed. If pin 11 is in the low state check Q20's base which should be at approximately +5 V. If it is not at +5 V one of the divider chain, IC1 through IC6, has failed to preset and this can be determined by checking the voltage at pins 12 and 11 of these ICs. The levels should all be greater than +2 V.

e. Clock Stops On Lower Ranges. This indicates that the divider network is not operating properly. Check to determine that the appropriate logic 1 is presented at the output of IC8 in all cases. If this does not define the problem, program in range 0 and determine that each of the decade counters is operating normally. This should isolate the problem.

f. Some Delay Ranges Missing. Check to determine that the output of IC2 produces a logical 1 on the range that is missing. If not, IC2 is defective. If it does, determine that the transistor associated with the timing capacitor on that range is in fact saturated for the range. If not, the problem is in the chain between the output of the MC4006 and the timing capacitor's switching transistor.

g. Some Width Ranges Missing. If the output of IC5 is producing a logical 1 on the desired range the problem is in the range switch transistor or its associated drive chain.

h. Width or Delay Ranges 3 and 5 Too Short. For the delay IC1 is defective or transistors Q7 or Q44 is defective. For the width circuit IC6 is defective or transistors Q16 or Q49 is defective.

i. No Output Pulse From Width Or Delay Board. The following is a quick procedure to localize the problem. Determine that the clock pulse appears on connector B of the width and delay card, pins 7 and 9. These two pulses should be reciprocals of each other. If the pulse is there the clock is operating correctly and the coaxial connections are satisfactory. Check the collector of Q30 to determine that the delay one-shot is programming correctly. Use a 5 K sampling probe. If no pulse appears here the delay one-shot has malfunctioned. Check the base of Q38 to determine that the width one-shot is operating correctly. No pulse at this point indicates that the width one-shot has malfunctioned. With an output board connected determine that there are drive pulses at pins C12 and C14 of the width and delay card. These pulses will be differentiated by the output board and will have an exponential character. If no pulses are present one of the following four transistors is bad or the normal inverted control circuitry has failed. Q38, Q39, Q40, and Q41 should be checked along with their associated circuitry.

j. No Output Pulse. First, determine the width drive pulse applied to J1 and J2 is present on both connectors. Next measure the voltage across C34 and if necessary adjust R201 to produce a −20 V ±0.1 V for this supply. Next measure the voltage across C35 and adjust, if necessary, R204 to produce a −15 ±0.15 V to this supply. If either or both of these power supplies will not adjust properly check the associated regulator on the power supply card. Next determine whether there is a negative output pulse present on the collector of the output transistors, Q62 and Q37. If this pulse is present the trouble is probably a bad balun connection or a defective relay. If the pulse is not present, observe the emitter of transistor Q27 which should be setting at approximately −19.5 V and should be producing a negative going pulse of at least 1.5 V amplitude. This test point is easily recognized as it is the triangular shaped piece mounted above the back of the board in the middle of the assembly. If this pulse is present the problem is either in the driver or in the output transistors, the 11780's, or possibly in their current source, transistor Q83. If a pulse is present at this point, but its level is wrong, check the clamping diodes, CR29, CR30, and CR31. If no pulse appears check the base of transistor Q55 and determine that a reasonable drive pulse is present. If there is a pulse at the base of Q55, approximately 1 V amplitude, the drive amplifier is operating properly. If not, the circuit must be trouble-shot from stage to stage. If there is a pulse present at this point and there is still no output pulse the level on the base of transistor Q27 will indicate whether the current source or the current sink is at fault and the circuitry is checked in a similar manner.

k. Calibration. If any extensive repairs are necessary to any of the modules of this instrument, that module alone should be completely recalibrated following the calibration procedure in this manual. It is not necessary to calibrate the D/A cards when repairs have been made to the functional boards and conversely when D/A cards have malfunctioned and have been replaced or repaired there is no need to recalibrate the functional module if the D/A cards are calibrated according to the procedure included in this manual.

SECTION 5
PARTS LIST

5-1 ORDERING INFORMATION

Replacement parts may be ordered through an E-H Representative or directly from the factory. To be certain of receiving the proper parts, always include the following information with the order:

a. Model number and serial number of the instrument on which the parts will be installed.

b. Circuit reference number and subassembly name, if applicable, for which the part is intended. If the part does not have a circuit reference, the description from the parts list should be used.

c. E-H part number.

The warranty is given on page ii of this manual, opposite the Table of Contents. For factory repair, contact the Customer Service Department of E-H Research Laboratories, Inc., at the address given on the title page of this manual. Include the following information:

a. Model number and serial number of the instrument on which the work is to be performed.

b. Details concerning the nature of the malfunction; or, type of repair desired.

5-2 HOW TO USE THIS PARTS LIST

The parts list is divided into subsections corresponding to the physical subsections of the instrument (printed circuit boards, chassis and subassemblies, miscellaneous hardware). Component locations can be determined from the schematic diagrams; each component appears only once in the parts list. At the beginning of each subsection are listed part numbers for any complete subassemblies in that category that are available as replacement parts. These subassemblies may include individually-listed components; care should be taken to locate malfunctions to the lowest possible level of replacement part and thus avoid the time and cost involved in "over-repair".

In the component descriptions, capacitor dielectrics are abbreviated as follows: polyethylene (poly.), ceramic (cer.), printed circuit (P.C.), electrolytic (elect.) and tantalum (tant.). Resistor and potentiometer values are given in ohms; the symbol for "ohm" (Ω) has been omitted. If no material is listed, resistors may be assumed to be carbon composition; other resistor types are metal film (MF) and wire-wound (WW). An asterisk following a component value indicates that the actual value is factory-selected at time of manufacture; the listed value is nominal.

ASSEMBLY NO. 251-21069

DESCRIPTION FRONT PANEL ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
250-21061	Panel	
630-00006	Switch, Toggle	
276-11946	Bezel	
510-00008	Light, Pilot	
596-00104	Resistor 100K ½W 5%	
	-HARDWARE-	
203-00037	#6-32x3/8 Lg OVALHMS 82° (6)	Prod Ref

ASSEMBLY NO. 253-21070

DESCRIPTION REAR PANEL ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
252-21062	Panel	
144-21066	Silkscreen	Prod Ref
262-20909	Bracket, 75 Pin Burndy	
721-00013	Connector, BNC	J102-105
700-00056	Connector, Burndy 75 Pin	J106-107
496-00025	Burndy Pin, Female 26AWG	
396-00001	Fuse Holder	F101,102
398-00002	Fuse 2A S.B	F101,102
700-00061	Receptacle, AC	J101
570-00008	Fan	B101
570-00009	Grill	
702-19177	Cable Harness	Prod Ref
702-19176	Wire List for 702-19177	Prod Ref

ASSEMBLY NO. 255-21071

DESCRIPTION MAIN CHASSIS ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
254-21063	Chassis	
144-21064	Silkscreen, Top	Prod Ref
144-21065	Silkscreen, Bottom	Prod Ref
650-19604	Transformer, Power	T301
484-00036	Terminal Strip	TB301
484-00037	Terminal Mtg. Strip	
484-00023	Terminal Strip Jumper	
258-13061	Cover, Terminal Strip	
484-00051	Feed thru Terminal USECO 4487B	
316-00073	Cap, E1, 5500µfd/40V	C301-304
316-00088	Cap, E1, 17,000µf/40V	C305
376-00066	Diode, Wastinghouse 368B	CR301,302
663-00073	Transistor, 2N3055	Q301-304
490-00001	Transistor Mtg Kit	
665-00074	IC LM309K N.S.	IC301
743-00011	Connector, PC	
484-00030	Card Guides	
484-00039	Card Guides	
262-21058	Bracket, Card Guides	

ASSEMBLY NO. 255-21071

DESCRIPTION MAIN CHASSIS ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
597-00152	Resistor 1.5K 1W 5%	R301,303
597-00102	Resistor 1K 1W 5%	R302,304
598-00151	Resistor 150Ω 2W 5%	R305
610-00135	Resistor .1Ω 5W w.w. OMI T-5	R306
704-23140	Coax Cable Assy, Signal	
	Input(Output Bd) Org	
704-23139	Coax Cable Assy, Signal	
	Input (Output Bd) Red	
702-21073	Cable Harness, Chassis	Prod Ref
702-21074	Wire List for 702-21073	Prod Ref
702-23010	Coax Wire List	Prod Ref
702-21075	Buss Wire List	Prod Ref
708-21076	Delay Line, 27ns	DL301
	-HARDWARE-	
202-00311	Screw #4-40x5/16 Lg BHMS (9)	Prod Ref
202-00305	Screw #4-40x½ Lg BHMS (38)	Prod Ref
203-00313	Screw #6-32x5/16 lg BHMS(15)	Prod Ref
203-00315	Screw #6-32x5/16 lg FLTHMS (8)	Prod Ref
203-00304	Screw, #6-32x⅜ Lg FLTHMS (4)	Prod Ref

ASSEMBLY NO. 401-19756

DESCRIPTION POWER SUPPLY BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
400-19755	PC Board	
401-19756	Assembly Drawing	Prod Ref
140-19757	Schematic	Prod Ref
311-00021	Cap, Cerm .05μfd 75V	
316-00044	Cap, El, 10μfd/25V	
376-00062	Diode, Motorola 1N4720	
374-00022	Diode, 1N751A	
376-00034	Diode, 1N4005	
595-00100	Resistor 10Ω ¼W 5%	
595-00101	Resistor 100Ω ¼W 5%	
595-00393	Resistor 39K ¼W 5%	
595-00102	Resistor 1K ¼W 5%	
595-00068	Resistor 6.8Ω ¼W 5%	
610-00088	Resistor .39Ω 2W 5% w.w.	
663-00070	Transistor, 2N3904	
663-00131	Diode, SCR, 2N4441	
665-00075	Regulator, IC, MFC 6030	
9616-00715	Resistor 5.11K ¼W 5% MF	
9616-00713	Resistor 1.82K ¼W 1% MF	

ASSEMBLY NO. 401-19977

DESCRIPTION TYPE B CLOCK BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
400-19976	PC Board	
401-19977	Assembly Drawing	Prod Ref
140-19978	Schematic	Prod Ref
311-00333	Cap, Dipped Mica 62pf	C4
311-00003	Cap, Cerm 25pf	C3
311-00034	Cap, Cerm .1µf 50V	C2
311-00010	Cap, Cerm .001µf 1KV 10%	C9,16,24
311-00074	Cap, Cerm .01µf 100V	C1,5,7, 10-12,15,
		19-21,23, 25-28
311-00007	Cap, Cerm 100pf 1KV 10%	C13
312-14972	Cap, Chip 0.1	C6
318-00005	Cap, Tant 10µf 20V	C8,14,17, 18,22,29
335-23309	Choke, 5T	L1,2
335-00001	Choke 1.5µh	L3-7
374-11761	Diode, MP	CR20A & B CR29A & B
376-00022	Diode, 1N914B	CR1-4, 6-17,25-28
376-00031	Diode, 1N270	CR30,31,32
9376-00700	Diode, MBD101	CR5,18,19, 21-24
551-	Beckman Helitrim 72XW Potentiometer 2K Series	R53
551- 00068	Beckman Helitrim 72XW Potentiometer 100Ω Series	R68

ASSEMBLY NO. 401-19977

DESCRIPTION TYPE B CLOCK BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
551-00069	Beckman Helitrim 72XW Potentiometer 100K Series	R26
594-00104	Resistor 100K 1/8W 5%	R8
594-00150	Resistor 15Ω 1/8W 5%	R42
594-00100	Resistor 10Ω 1/8W 5%	R3,6,7,9,
		10,14,17,62,
		63,66,45,
		58,72,81,
		82
595-00102	Resistor 1K ¼W 5%	R13,15,30,
		33,50,76,78
		86,90,95,97
		102
595-00302	Resistor 3K ¼W 5%	R31,32,34,
		73,74
595-00471	Resistor 470Ω ¼W 5%	R29,36,
		37,39
595-00101	Resistor 100Ω ¼W 5%	R27,84,
		94,103
595-00100	Resistor 10Ω ¼W 5%	R91,108,
		112-115
595-00391	Resistor 390Ω ¼W 5%	R43,98
595-00152	Resistor 1.5K ¼W 5%	R38,41,64
		75,80,123
595-00153	Resistor 15K ¼W 5%	R20
595-00123	Resistor 12K ¼W 5%	R22
595-00162	Resistor 1.6K ¼W 5%	R16
595-00820	Resistor 82Ω ¼W 5%	R79,83
595-00222	Resistor 2.2K ¼W 5%	R77

ASSEMBLY NO. 401-19977

DESCRIPTION TYPE B CLOCK BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
595-00271	Resistor 270Ω ¼W 5%	R46,57
595-00121	Resistor 120Ω ¼W 5%	R44
595-00182	Resistor 1.8K ¼W 5%	R99,106
595-00470	Resistor 47Ω ¼W 5%	R122, 124
595-00910	Resistor 91Ω ¼W 5%	R65,71,92, 93,109,110
595-00122	Resistor 1.2K ¼W 5%	R61,70, 117,116
595-00821	Resistor 820Ω ¼W 5%	R111
595-00151	Resistor 150Ω ¼W 5%	R12
595-00392	Resistor 3.9K ¼W 5%	R85,101
595-00472	Resistor 4.7K ¼W 5%	R100,107
595-00103	Resistor 10K ¼W 5%	R96
595-00912	Resistor 9.1K ¼W 5%	R104
595-00332	Resistor 3.3K ¼W 5%	R28,105
595-00242	Resistor 2.4K ¼W 5%	R87-89
595-00056	Resistor 5.6Ω ¼W 5%	R121
595-00272	Resistor 2.7K ¼W 5%	R56,
596-00751	Resistor 750Ω ½W 5%	R119
597-00511	Resistor 510Ω 1W 5%	R35,54
9616-00705	Resistor 221Ω ¼W 1% MF	R60

ASSEMBLY NO. 401-19977

DESCRIPTION TYPE B CLOCK BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
617-	Resistor 105Ω ¼W 1% MF	R69
9616-00714	Resistor 3.32K ¼W 1% MF	R24
617-00033	Resistor 200Ω ¼W 1% MF	R2,4,49,51
617-00007	Resistor 2.21K ¼W 1% MF	R1,5,11
617-00317	Resistor 1.5K ¼W 1% MF	R19
617-00003	Resistor 2K ¼W 1% MF	R18
617-00065	Resistor 18.2K¼W 1% MF	R21
617-00059	Resistor 48.7K ¼W 1% MF	R25
617-00021	Resistor 1.82K ¼W 1% MF	R67
9616-00715	Resistor 5.11K ¼W 1% MF	R23
9616-00723	Resistor 2.37K ¼W 1% MF	R47
9616-00724	Resistor 3.57K ¼W 1% MF	R48,52
9616-00316	Resistor 1K ¼W 1% MF	R55
595-00241	Resistor 240Ω ¼W 5%	R118,120
663-00112	Transistor MPS 2369	Q7,14,15, 18,19,21-24
		29,30,33-36 47-49
663-11757	Transistor	Q2-6,8-10, 31,32,41,42
		45,46
9663-00700	Transistor MPS 3904 NPN	Q11,12,17, 20,26-28,
		47-40

ASSEMBLY NO. 401-19977

DESCRIPTION TYPE B CLOCK BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
9663-00701	Transistor MPS 3906 PNP	Q1,13,16, 25,43,44
665-00062	IC MC 3006P	IC 12
665-00057	IC MC 4006P	IC 8
665-00076	IC MC 7490P or SN7490N	IC 1-6
665-00077	IC SN 47196N	IC 7
665-00053	IC MC 3000P	IC9-11,13 14

ASSEMBLY NO. 401-18961

DESCRIPTION TYPE A DELAY & WIDTH BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
400-18960	PC Board	
401-18961	Assembly Drawing	Prod Ref
140-18962	Schematic	Prod Ref
311-00010	Cap, Cerm .001µf 1KV 10%	C1,2,9,11, 14,19,21,33
		34-36,38 39,18
311-00064	Cap, Cerm 100pf HiQ	C4,13
311-00034	Cap, Mono .1µf/50V	C3,7,12, 23,37
311-00069	Cap, Cerm .005 Foil Tab 500V 10%	C5,6,16,17
311-00020	Cap, Mono .47µf 20V	C10,15
311-00073	Cap, Cerm 500V Foil Tab 500pf 10%	C24
311-00300	Cap, Mica 150pf	C8,22
318-00005	Cap, Tant, 10µf 20V	C30-32
320-00069	Cap, Mylar .018 200V 1%	C25,29
320-00070	Cap, Mylar 1.8µf 200V 1%	C26,28
320-00077	Cap, .0016µf 50V 2% (SEI) #22U-A162G	C20,27
335-00001	Choke 1.5µh	L5-7
374-00044	Diode, 1N749A	CR15
374-11731	Diode, MP	CR4,5
374-12529	Diode, Zener	CR27

ASSEMBLY NO. 401-18961

DESCRIPTION TYPE A DELAY & WIDTH BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
376-00022	Diode, 1N914B	CR1,18-20, 30,43-45
376-11764	Diode	CR2,3,12, 21,22,37,40
9376-00700	Diode, MBD 101	CR6-11,13, 14,16,17,
		23-26,28,29 31-36,38,39
		41,42
551-00062	Helitrim 62P Potentiometer 10K	R136,179
551-00070	Helitrim 72XW Series Potentiometer 200Ω Beckman	R17,60
551-00071	Helitrim 72XW Series Potentiometer 500Ω Beckman	R21,26,46, 52
551-00301	Helitrim 62P Potentiometer 2K	R138,185
595-00036	Resistor 3.6Ω ¼W 5%	R80,97
595-00051	Resistor 5.1Ω ¼W 5%	R83,84,95 96,127,128
		174,126, 176,177
595-00100	Resistor 10Ω ¼W 5%	R1,25,51
595-00102	Resistor 1K ¼W 5%	R31,56, 111-113,
		116-119,121 133,156,167
		168,183, 192-195,200
595-00101	Resistor 100Ω ¼W 5%	R4,6,7,13, 33,35,37,
		42,69,70,72 93,104,108
595-00104	Resistor 100K ¼W 5%	R82
595-00105	Resistor 1M ¼W 5%	R124,125,180 129,171,172

ASSEMBLY NO. 401-18961

DESCRIPTION TYPE A DELAY & WIDTH BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
595-00103	Resistor 10K ¼W 5%	R120,131,
		140,142,144
		164-166,169
		170,175,190
		191,196,
		197
595-00152	Resistor 1.5K ¼W 5%	R62,64
595-00182	Resistor 1.8K ¼W 5%	R5,65
595-00200	Resistor 20Ω ¼W 5%	R30,98
595-00201	Resistor 200Ω ¼W 5%	R73,91
595-00202	Resistor 2K ¼W 5%	R158,159
595-00203	Resistor 20K ¼W 5%	R162
595-00221	Resistor 220Ω ¼W 5%	R78,148,149
595-00222	Resistor 2.2K ¼W 5%	R23,48,145
		146,163,198
		199
595-00241	Resistor 240Ω ¼W 5%	R11
595-00301	Resistor 300Ω ¼W 5%	R41,66
595-00302	Resistor 3K¼W 5%	R85,100
595-00391	Resistor 390Ω ¼W 5%	R101,103,
		109,157,160
595-00431	Resistor 430Ω ¼W 5%	R67
595-00471	Resistor 470Ω ¼W 5%	R106
595-00681	Resistor 680Ω ¼W 5%	R92
595-00682	Resistor 6.8K ¼W 5%	R32,57

ASSEMBLY NO. 401-18961

DESCRIPTION TYPE A DELAY & WIDTH BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
595-00750	Resistor 75Ω ¼W 5%	R86,87
595-00752	Resistor 7.5K ¼W 5%	R8,36,110
595-00820	Resistor 82Ω ¼W 5%	R74,75, 153,141
595-00910	Resistor 91Ω ¼W 5%	R19,58
595-00912	Resistor 9.1K ¼W 5%	R81,99
595-00510	Resistor 51Ω ¼W 5%	R15,29, 44,50
595-00153	Resistor 15K ¼W 5%	R49,114, 132,161,
		188,189
596-00102	Resistor 1K ½W 5%	R112,123, 130,181,
		182,187
596-00122	Resistor 1.2K ½W 5%	R12,40
596-00331	Resistor 330Ω ½W 5%	R63
596-00361	Resistor 360Ω ½W 5%	R89
596-00511	Resistor 510Ω ½W 5%	R152,154
596-00561	Resistor 560Ω ½W 5%	R105
596-00751	Resistor 750Ω ½W 5%	R79,88, 94,102
596-00821	Resistor 820Ω ½W 5%	R68,71,76, 77,90,143,
		147,150, 151,155
616-00307	Resistor 348Ω 1/8W 1% MF	R18,61
616-00336	Resistor 15K 1/8W 1% MF	R16,59

ASSEMBLY NO. 401-18961

DESCRIPTION TYPE A DELAY & WIDTH BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
9616-00305	Resistor 200Ω 1/8W 1% MF	R10,38
9616-00316	Resistor 1K 1/8W 1% MF	R2,134, 135,186,201
9616-00320	Resistor 2K 1/8W 1% MF	R3,9,139, 39,184
9616-00334	Resistor 10K 1/8W 1% MF	R24,34, 137,178
9616-00707	Resistor 392Ω 1/8W 1% MF	R28,55
9616-00714	Resistor 3.32K 1/8W 1% MF	R27,54
9616-00720	Resistor 511Ω 1/8W 1% MF	R14,43
9616-00724	Resistor 3.57K 1/8W 1% MF	R22,47
9617-00044	Resistor 845Ω 1/8W 1% MF	R20,45
	Resistor 1/2W Select Factory	R107
663-00112	Transistor MPS 2369	Q12,19,25, 27,29,30,34
		38, 39 33
663-11757	Transistor 11757	Q20-24,26, 40,31,32,
		35-37,41
9663-00700	Transistor MPS 3904	Q1,5,9,14, 17,28,44,
		48,49,53, 54,55,60,61
		64,65,67
9663-00701	Transistor MPS 3906	Q2-4,6-8, 10,11,13,15
		16,18, 45 ,50-52
		57-59,62,63 68

ASSEMBLY NO. 401-18961

DESCRIPTION TYPE A DELAY & WIDTH BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
665-00078	IC MC 3004P	IC 1,3,4,6
665-00057	IC MC 4006P	IC 2,5
704-23336	Clipping Line 10" RG195	CL 1-4
663-00129	Transistor , 2N4403	Q42,43,46, 47,56,66
	-HARDWARE-	
	Clamp, Cable (1)	Prod Ref
	Screw, 2-56 (1)	Prod Ref
	Nut 2-56 (1)	Prod Ref

ASSEMBLY NO. 401-20929

DESCRIPTION BUFFER BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
400-20928	PC Board	
401-20929	Assembly Drawing	Prod Ref
140-20930	Schematic	Prod Ref
311-00074	Cap., .01μf 100V	C1
376-00022	Diode, 1N914B	CR1,2
595-00102	Resistor 1K ¼W 5%	R3
595-00103	Resistor 10K ¼W 5%	R4
595-00681	Resistor 680Ω ¼W 5%	R2
595-00682	Resistor 6.8K ¼W 5%	R1
663-00071	Transistor 2N3906	Q1
663-11724	Transistor	Q2
665-00053	IC MC 3000P	IC 8-14
665-00078	IC MC 3004 P	IC 1-7
495-00040	IC Sockets	

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
400-20457	PC Board	
401-20458	Assembly	Prod Ref
140-20459	Schematic	Prod Ref
311-00002	Cap, Cerm 20pf 1KV	C41,42
311-00007	Cap, Cerm 100pf 1KV 10%	C1
311-00010	Cap, Cerm .001µf	C2-5,37,45
311-00011	Cap, Cerm .005µf	C39
311-00034	Cap, Cerm .1µf 50V	C16,26,32, 33,46
311-00064	Cap, Cerm 100pf Hi-Q 10%	C10
311-00074	Cap, Cerm .01µf 100V	C17,18,36, 44,47-50
311-00072	Cap, Cerm 22pf Hi-Q	C19
311-00097	Cap, Mica 56pf 5%	C11
311-00098	Cap, Mica, 620pf 1%	C9
312-14974	Cap, Chip .01	C14
312-14971	Cap, Chip 390pf	C13
312-14972	Cap, Chip .1µf	C12,15,24, 25,38
318-00019	Cap, Tant, 47µf 20V	C20-23
318-00005	Cap, Tant 10µf 20V	C27-31,35
318-00038	Cap, Tant 5.6µf 35V	C34,40

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
320-00074	Cap, Poly .075pf 1%	C7
320-00076	Cap, Poly .75pf 1%	C6
326-00026	Cap, poly 6750pf 1%	C8
332-00010	Cap, Variable 2.5-9pf	C43
335-00022	Choke 1μh	L17-21
335-12607	Choke 13T (1) 4C4	L10
335-14686	Choke 5T (1) 4C4	L1-4
335-17303	Choke 10T (1) 3E2A	L11
335-23467	Choke 10T (4) 4C4	L15
335-23469	Choke 8T (1) 4C4	L16
335-19184	Choke 20T (2) 3D3	L12-14
361-00012	Core, 4C4	L5
374-00022	Diode, Zener 1N751A	CR22
374-00037	Diode, Zener 1N759A	CR9
374-00044	Diode, 1N749A	CR11
374-11733	Diode, MP 1N759A	CR12A&B
374-11761	Diode, MP	CR7A&B
376-00022	Diode, 1N914B	CR1-4,6,10 14-21,23-26 32-41
9376-00700	Diode, MBD101	CR29-31

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
490-00020	Heat Sink	XQ27
490-00045	Heat Sink (IERC-PA1-1CB)	XR129, XQ42,43,83
490-00046	Heat Sink (IERC-PB1-3CB)	XQ26
490-17108	Heat Sink Plate	XQ37,62
490-00041	Pad, Transistor Insulator TO-18	
490-00048	Heat Sink (Wake. 26010SH5)	XQ28,59,60
490-17026	Heat Sink	XQ37,62
490-23128	Heat Sink Plate	XR129, XQ42,43,83
490-16574	Heat Sink Plate	XQ26
496-00029	Pad, Transistor Insulator TO-5	
495-00027	Amp Pins	XQ27,28 57-60
551-00038	Potentiometer 2K	R201,204
551-00072	Potentiometer 50Ω	R71
551-00068	Potentiometer 100Ω	R104
551-00070	Potentiometer 200Ω	R94
551-00073	Potentiometer 1K	R31,55
551-00074	Potentiometer 2K	R7
551-00075	Potentiometer 50K	R25,34,65
551-00076	Potentiometer 500K	R57
584-00019	Relay, Hi-G	K1-4

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
584-00018	Relay, Zestron 226-12-1A	K5
594-00039	Resistor 3.9Ω 1/8W 5%	R164
594-00051	Resistor 5.1Ω 1/8W 5%	R128
594-00056	Resistor 5.6Ω 1/8W 5%	R75
594-00750	Resistor 75Ω 1/8W 5%	R95,110, 111,117,118
595-00027	Resistor 2.7Ω ¼W 5%	R8,
595-00036	Resistor 3.6Ω ¼W 5%	R44,47
595-00100	Resistor 10Ω ¼W 5%	R40,60,72 120,125,
		198,199, 214
595-00102	Resistor 1K ¼W 5%	R41,59,79, 80,86,102,
		154,155, 166-169,206
595-00103	Resistor 10K ¼W 5%	R21,37, 156-158
595-00105	Resistor 1M ¼W 5%	R159-163, 211
595-00124	Resistor 120K ¼W 5%	R56
595-00152	Resistor 1.5K ¼W 5%	R183,186, 188,190
595-00200	Resistor 20Ω ¼W 5%	R61,62
595-00201	Resistor 200Ω ¼W 5%	R9
595-00202	Resistor 2K ¼W 5%	R78,91
595-00222	Resistor 2.2K ¼W 5%	R14,19,88 107, 150

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
595-00223	Resistor 22K ¼W 5%	R10
595-00271	Resistor 270Ω ¼W 5%	R58,165
595-00300	Resistor 30Ω ¼W 5%	R66,127
595-00302	Resistor 3K ¼W 5%	R101
595-00330	Resistor 33Ω ¼W 5%	R42,43
595-00332	Resistor 3.3K ¼W 5%	R5,92,106
595-00333	Resistor 33K ¼W 5%	R11,12,49
595-00361	Resistor 360Ω ¼W 5%	R73,74
595-00362	Resistor 3.6K ¼W 5%	R76
595-00390	Resistor 39Ω ¼W 5%	R63
595-00391	Resistor 390Ω ¼W 5%	R174,178, 208
595-00393	Resistor 39K ¼W 5%	R196
595-00394	Resistor 390K ¼W 5%	R33
595-00471	Resistor 470Ω ¼W 5%	R191-194 207
595-00472	Resistor 4.7K ¼W 5%	R195,197
595-00510	Resistor 51Ω ¼W 5%	R15,17,18 99,215
595-00511	Resistor 510Ω ¼W 5%	R100
595-00512	Resistor 5.1K ¼W 5%	R121,175
595-00560	Resistor 56Ω ¼W 5%	R112
595-00563	Resistor 56K ¼W 5%	R23,27,35 50,67

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
595-00680	Resistor 68Ω ¼W 5%	R77
595-00682	Resistor 6.8K ¼W 5%	R83,87,103
595-00683	Resistor 68K ¼W 5%	R147-149, 151-153
595-00822	Resistor 8.2K ¼W 5%	R69
595-00910	Resistor 91Ω ¼W 5%	R64
596-00102	Resistor 1K ½W 5%	R108
596-00122	Resistor 1.2K ½W 5%	R180,209
596-00151	Resistor 150Ω ½W 5%	R113
596-00241	Resistor 240Ω ½W 5%	R182,184, 187,189
596-00471	Resistor 470Ω ½W 5%	R213
596-00681	Resistor 680Ω ½W 5%	R16,170-173
597-00241	Resistor 240Ω 1W 5%	R45
597-00431	Resistor 430Ω 1W 5%	R126
597-00621	Resistor 620Ω 1W 5%	R181
598-00131	Resistor 130Ω 2W 5%	R210
610-00019	Resistor 10Ω 3W w.w.	R179
610-00136	Resistor 18Ω 3W w.w.	R89,109
616-00325	Resistor 4.22K 1/8W 1% MF	R30

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ITEM	ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
A	616-00331	Resistor 7.5K 1/8W 1% MF	R176
B	616-00332	Resistor 9.09K 1/8W 1% MF	R81,200
C	9616-00704	Resistor 162Ω ¼W 1% MF	R32
D	9616-00726	Resistor 1.5K ¼W 1% MF	R53
E	617-00002	Resistor 1K ¼W 1% MF	R24,38,54, 84,85,202
F			205
G	617-00003	Resistor 2K ¼W 1% MF	R22,36
H	617-00009	Resistor 976Ω ¼W 1% MF	R105
I	617-00010	Resistor 4.02K ¼W 1% MF	R203
J	617-00011	Resistor 4.99K ¼W 1% MF	R29
K	617-00012	Resistor 10K ¼W 1% MF	R2,13,20, 26,39
L	617-00013	Resistor 20K ¼W 1% MF	R28,48, 51,68
M	617-00035	Resistor 8.06K ¼W 1% MF	R4,6
N	617-00036	Resistor 16.2K ¼W 1% MF	R1
O	617-00023	Resistor 1.1K ¼W 1% MF	R93,177
P	617-00047	Resistor 5.62K ¼W 1% MF	R90
Q	617-00056	Resistor 2.49K ¼W 1% MF	R52
R	617-00065	Resistor 18.2K ¼W 1% MF	R82
S	617-00057	Resistor 19.1K ¼W 1% MF	R212
T	617-00089	Resistor 130Ω ¼W 1% MF	R70

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
617-00714	Resistor 3.32K ¼W 1% MF	R3
618-00116	Resistor 10Ω ½W 1% MS150	R96-98 114-116
619-00006	Resistor 25.5Ω 1W MS220	R119,124
619-00007	Resistor 51Ω 1W 1% MS210	R122,123
622-00050	Resistor 75Ω 2W 1% MS220	R130,134
622-00051	Resistor 150Ω 2W 1% MS220	R135,136
622-00052	Resistor 93.1Ω 2W 1% MS220	R131-133
622-00053	Resistor 165Ω 2W 1% MS220	R137-142 145,146
622-00054	Resistor 82.5Ω 2W 1% MS220	R143,144
623-00001	Resistor 65Ω 15W 1% MP312	R129
651-12570	Transformer	T1
651-19186	Transformer, Balun	T2
663-00070	Transistor 2N3904 NPN	Q3,6,10,13 14,17,22,24
		33,35,39,40 45,48,53,61
		63-66,73-75 86
663-00071	Transistor 2N3906 PNP	Q1,2,4,5, 11,16,20,23
		25,30-32,34 36,38,41,46
		47,52,67-72 82,84,88,89
663-00106	Transistor 2N4919	Q21,26,43

ASSEMBLY NO. 401-20458

DESCRIPTION TYPE C OUTPUT BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
663-00107	Transistor 2N4923	Q42,83
663-00108	Transistor 2N5841	Q27
663-00109	Transistor A210	Q28,59,60
663-00112	Transistor MPS 2369	Q50,51
663-00129	Transistor 2N4403	Q76-79
663-00130	Transistor 2N5086	Q9,15,49
663-11724	Transistor	Q12,29,85
663-11725	Transistor	Q54,87
663-11757	Transistor	Q7,8,18,19 55,56
663-11780	Transistor 2N5635	Q37,62
663-11781	Transistor 11749 Sel	Q57,58
665-00053	IC MC 3000P	IC 2,3
665-00080	IC SN7445	IC 1
280-20908	Plate, Connector Mtg.	
704-23138	Output Cable Assembly	J108
715-23086	Connector Strip Line	
721-00052	Connector, Micon	J1,2
410-00020	Component Clip (1)	Prod Ref
484-00051	Washer, Teflon (1)	Prod Ref

ASSEMBLY NO. 401-20932

DESCRIPTION PARALLEL D/A CONVERTER BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
400-20931	PC Board	
401-20932	Assembly Drawing	Prod Ref
140-20933	Schematic	Prod Ref
311-00001	Cap, Cerm, 10pf 1KV	C6
311-00074	Cap, Cerm, .01μf	C1,3,5
318-00005	Cap, Tant 10μf 20V	C2,4
551-00040	Potentiometer, 1K	R3
551-00039	Potentiometer, 200Ω	R6
595-00100	Resistor 10Ω ¼W 5%	R1,2
595-00222	Resistor 2.2K ¼W 5%	R23-34
595-00822	Resistor 6.8K ¼W 5%	R10
595-00394	Resistor 390K ¼W 5%	R14
595-00824	Resistor 820K ¼W 5%	R13
595-00165	Resistor 1.6M ¼W 5%	R12
595-00335	Resistor 3.3M ¼W 5%	R11
611-00001	Vishay Type V-53-1 Resistor 4K 0.05%	R22
611-00002	Vishay Type V-53-1 Resistor 8K 0.1%	R21
611-00003	Vishay Type V-53-1 Resistor 16K 0.1%	R20
611-00004	Vishay Type V-53-1 Resistor 32K 0.1%	R19

ASSEMBLY NO. 401-20932

DESCRIPTION PARALLEL D/A CONVERTER BOARD ASSEMBLY

ASSEMBLY OR PART NO.	DESCRIPTION	SCHEMATIC REF.
616-00342	Resistor 40.2K 1/8W 1% MF	R18
616-00347	Resistor 80.6K 1/8W 1% MF	R17
616-00015	Resistor 165K 1/8W 1% MF	R16
616-00016	Resistor 316K 1/8W 1% MF	R15
616-00017	Resistor 3.32K 1/8W 1% MF	R9
616-00326	Resistor 4.42K 1/8W 1% MF	R7
616-00332	Resistor 9.09K 1/8W 1% MF	R5
616-00330	Resistor 6.19K 1/8W 1% MF	R4
663-00070	Transistor, 2N3904	Q2-13
665-00079	IC Signetics UA741CT	IC 4
665-00053	IC MC 3000P	IC 1-3
495-00040	IC Sockets	
495-00027	Amp Pins	

SECTION 6
DRAWINGS

6-1 GENERAL INFORMATION

This section of the manual contains drawings of the subassemblies and circuits in the E-H Model 1501 Pulse Generator. The drawings contain the component circuit designators and show the location of the wiring terminals. The theory of operation is located in Section 3 and the parts list is located in Section 5.

Figure 6-1 is an outline dimension drawing of the bench top configuragion. Figures 6-2 through 6-4 are the component location drawings. Refer to the drawings to determine the location of any specific component.

6-2 SCHEMATIC DIAGRAMS

There are five schematics following the component location drawings. Insofar as possible, the convention of signal-flow from left to right and current-flow from bottom to top are adhered to in the diagrams.

Component symbology and nomenclature follow generally-accepted practices. Resistance is given in ohms. Capacitor values less than 1 are in microfarads and more than 1 are in picofarads unless otherwise labeled. Multi-deck rotary switches are shown schematically inline.

REVISIONS						
LTR	REVISION	DATE	DRAWN	CHK'D	APPR'D	ECO
A	ORIGINAL RELEASE					
B	ADD FUNCTION TITLES TO J102 THRU 108 ADD PINS 19, 20 & 21 TO J 309; AND NOTE 2 COAX W/L WAS 191801 BUSS W/L WAS 191811	2/16/72	DCM	4/4/72		PEN 20
C	J303C PINS M WAS N & PIN N WAS R ADD DELAY LINE, RE-NUMBER J305 THRU J316	10/20/72	REM	REM		ECO 73-045

F-20910 C

EXT. PROGRAMMING

J106 J107

+5V.

J 316 P.C. BOARD NOT USED

J 305 P.C. BOARD NOT USED 3,C 4,D 5,E 6,F 7,H 8,J 9,K

D/A (WIDTH) J 306
P.C. FAB. 400-20931
ASSY. 401-20932
SCHEM. 140-20933

D/A (DELAY) J 307
P.C.B. FAB. 400-20931
ASSY. 401-20932
SCHEM. 140-20933

D/A (FREQ.) J 308
P.C.B. FAB. 400-20931
ASSY. 401-20932
SCHEM. 140-20933

BUFFER J 309 A & B
P.C.B. FAB. 400-20928
ASSY. 401-20929
SCHEM. 140-20930

+15V B-1A B-2B -15V

+5V B-3C B-4D

D/A (OFFSET) J 312
P.C.B. FAB. 400-20931
ASSY. 401-20932
SCHEM. 140-20933

D/A (AMP) J 313
P.C.B. FAB. 400-20931
ASSY. 401-20932
SCHEM. 140-20933

D/A (- RAMP) J 314
P.C.B. FAB. 400-20931
ASSY. 401-20932
SCHEM. 140-20933

D/A (+ RAMP) J 315
P.C.B. FAB. 400-20931
ASSY. 401-20932
SCHEM. 140-20933

GATE SYNC J 105
EXT. CLOCK IN J 103
TRIGGER OUT J 102

DELAY LINE 708-21076 27 ns

CLOCK J 301 B & C
P.C.B. FAB. 400-19976
ASSY. 401-19977
SCHEM. 140-19978

+15V +5V -15V

DELAY / WIDTH J 302 B & C
P.C.B. FAB. 400-18960
ASSY. 401-18961
SCHEM. 140-18962

OUTPUT J 303A, B & C
P.C.B. FAB. 400-20457
ASSY. 401-20458
SCHEM. 140-20459

RED ORG

OUTPUT J 108

+15V +5V -15V

GATE ASYNC J 104

234 VOLT OPTION 50-60 Hz
100 VOLT OPTION 50-60 Hz
LINE

F 101 1 A. S.B.
F 102 1 A. S.B.
F 101 2 A. S.B.
F 102 2 A. S.B.

TB 301

J101 AC INPUT

S201 POWER ON

F101 2 AMP S.B.
F102 2 AMP S.B.

R201 100K

DS 201

B101 FAN

TB 301 117 V. 50-60 Hz

T 301 650-19604

63 VAC NOT USED

R 306 .1Ω 5W

CR301 376-00066
CR302 376-00066

C 305 15,000 Mfd. 40V

R305 150Ω 2W

LC.301 5V REG.

+5V.

R303 1.5K, 1W

Q301 663-00073

C 303 5500 Mfd. 40V

RED BROWN RED SLATE SLATE ORANGE ORANGE WHITE GREEN GREEN WHITE/RED WHITE/RED YELLOW YELLOW

POWER SUPPLY REGULATOR J 310
P.C.B. FAB. 400-19755
ASSY. 401-19756
SCHEM. 140-19757

+15V. GROUND -15V.

C304 5500 Mfd 40V.

R304 1K, 1W.

Q304 663-00073

C301 5500 Mfd 40V.

Q302 663-00073

R301 1.5K, 1W

Q303 663-00073

5500 Mfd 40V. C302

R302 1K, 1W

NOTES: UNLESS OTHERWISE SPECIFIED

1. VOLTAGES TO ALL CONNECTORS EXCEPT J 301C, J 302C, J 303C, J 308B AND J 309 ARE CONNECTED TO PINS AS FOLLOW:
   +15 VOLTS PINS 22 AND Z
   -15 VOLTS PINS 21 AND Y
   +5 VOLTS PINS 20 AND X
   GROUND PINS 19 AND W
   VOLTAGES ON CONNECTORS J 301C, J 302C, J 303C, J 308B AND J 309 ARE CONNECTED TO PINS AS SHOWN

2. REFERENCE:
   WIRE LIST J 106 - J 107 A-702-19176
   HARNESS DRAWING J 106 - J 107 D-702-19177
   WIRE LIST CHASSIS A-702-19178
   HARNESS DRAWING CHASSIS D-702-19179
   WIRE LIST COAX A-702-23010
   WIRE LIST BUSS A-702-23011

ITEM NO.	PART NO.	DESCRIPTION	QTY.

MATERIAL LIST

UNLESS OTHERWISE SPECIFIED
SCALE: NONE.
FRACTIONAL ± 1/64
DECIMALS .X ± .03
.XX ± .010
ANGLES ± 1°
DO NOT SCALE DRAWING

E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA

TITLE
MASTER SCHEMATIC

DRAWN	RCM	12-1-71	SIZE
CHK'D	[illegible]	12-7-71	F-20910 C
APP'D			SHEET 1 of 1

DWG. NO. 1501
USED ON 1501
NEXT ASSY 825-20994

C-6 WIDTH VERNIER

FULL SCALE ADJ

4/6 MAX ADJ

DELAY VERNIER

B-D

CLOK INPUTS

B-H

B-T

B-J

B-K

GATE

B-11

DELAY RANGE INPUTS

B-14

B-15

B-16

C-18 Y DOUBLE PULSE

C-10 Y1 C-9 Y2 C-8 Y4 WIDTH RANGE

C-7 N/I

C-12 C-14 DRIVE OUT C-M C-R

MIN ADJ.

4/6 MIN ADJ.

1 MIN ADJ.

4/6 MIN ADJ

REVISIONS						
ISSUE	REVISION	DATE	DRAFTS CHK'D	APPR'D	ECO
A	ORIGINAL RELEASE	—	—	—	—
B	REVISED SEE OBS REVISION A	12-7-71	RDA	MSE	W	374
C	Q42,43,46,47,56 & 66 WERE 9663-00701	4-5-72	RDA	MSE	W	377

F-18962 C

NOTES: (UNLESS OTHERWISE NOTED)

1. ALL RESISTORS ARE IN OHMS, 1/4 W, 5%, CARBON.
2. ALL MF RESISTORS ARE 1/8 W.
3. ALL CAPACITORS ARE IN μF.
4. ALL DIODES ARE 9376-00700.
5. ALL I.C.S PIN 14 VCC, PIN 7 GND.
6. I.C. 1-3-4-6 ARE MC 3004P.
7. I.C. 2-5 ARE 665-00057.
8. TRANSISTORS
   Q12, 13, 25, 27, 29, 30, 33, 34, 38, & 39, ARE 663-00112.
   Q20, 21, 22, 23, 24, 26, 31, 32, 35, 36, 37, 40, & 41, ARE 663-11757.
   Q1, 5, 9, 14, 17, 28, 44, 48, 49, 53, 54, 55, 60, 61, 64, 65, & 67, ARE 9663-00700.
   Q 2, 3, 4, 6, 7, 8, 10, 11, 13, 15, 16, 18, 45, 50, 51, 52, 57, 58, 59, 62, 63, & 68, ARE 9663-00701
9. REFERENCE DRAWINGS
   P.C.B. FAB 400-18960
   " ASSY. 401-18961
10. CL1 - CL4 ARE CLIPPING LINES

400-18960

MATERIAL LIST

E-H RESEARCH LABORATORIES, INC. OAKLAND, CALIFORNIA

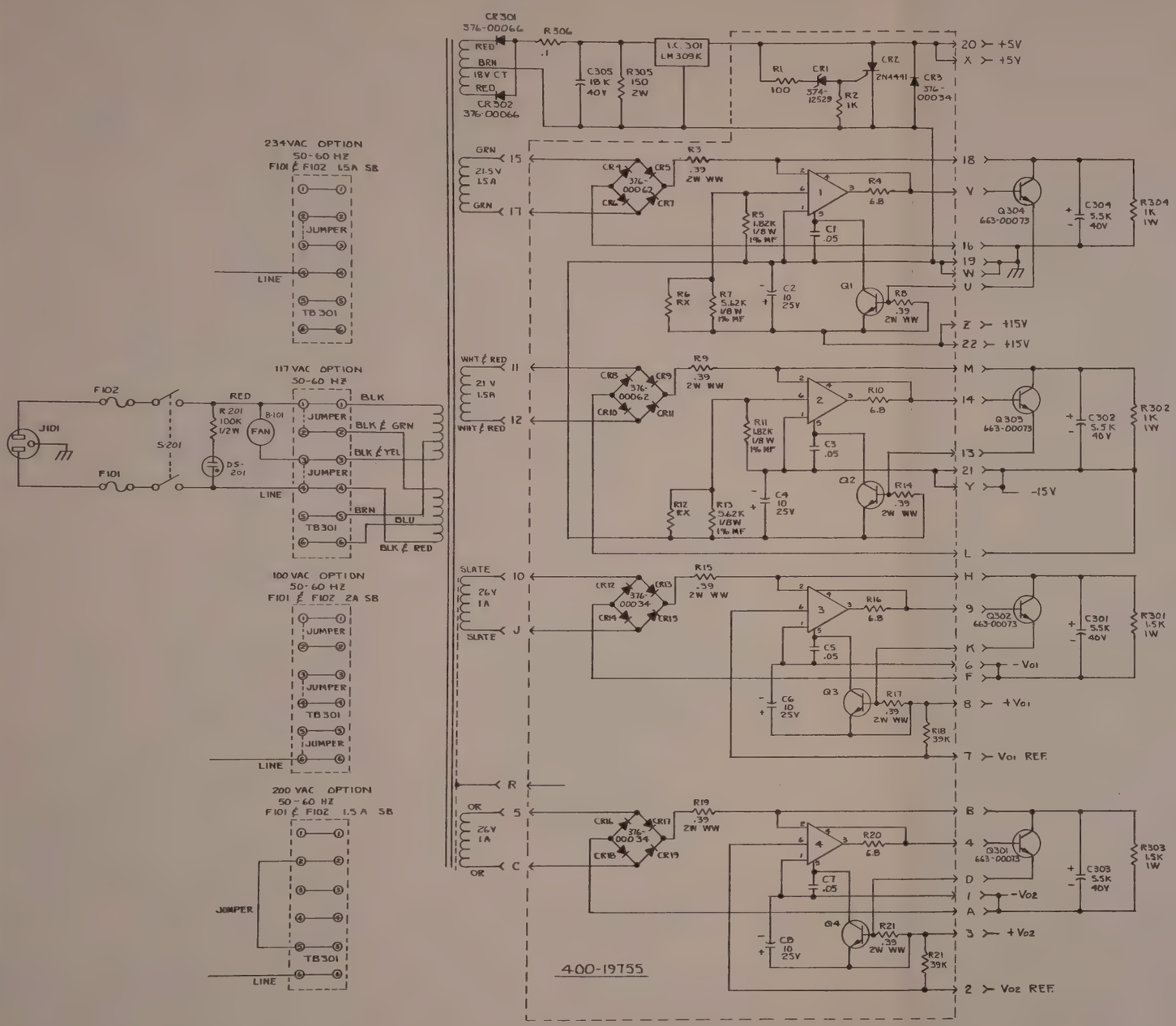
TITLE: SCHEMATIC, DELAY & WIDTH BOARD

DRAWN	ABM	11-18-71	SIZE C
CHK'D	RDA	12-1-71	F-18962
APP'D			SHEET 1 OF 1 SHEETS

1501 | 401-18961 | ASSY

F-19757 | B

REVISIONS						
A	ORIGINAL RELEASE	—	—	—	—	—
B	CR1 WAS IN754A	6/16/72	GA	GA	[illegible]	72-033



NOTES: (UNLESS OTHERWISE NOTED)

1. ALL RESISTORS ARE IN OHMS.
2. ALL CAPACITORS ARE IN μf.
3. ALL TRANSISTORS ARE 663-00070.
4. IC1-4 ARE MFC 6030
5. REFERENCE DRAWINGS:
   P.C.B. FAB. 400-19755
   " ASSY. 401-19756.

ITEM NO.	PART NO.	DESCRIPTION	QTY

MATERIAL LIST

UNLESS OTHERWISE SPECIFIED
DECIMALS: 2 PLACES ± .01
FRACTIONS: ± 1/64
ANGLES: ± 1°
DO NOT SCALE DRAWING

E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA

TITLE: SCHEMATIC: P.C.B. POWER SUPPLY

	INITIALS	DATE
DRAWN	ABM	1.13.72
CHKD	[illegible]	1/18/72
APPD		

SIZE: B | CODE IDENT NO.: 1501 | DWG NO.: F-19757 | REV: B

SCALE: NONE | SHEET 1 OF 1 | 1501

FREQ V IN C8 B2 B8 GATE IN

B8 GATE ON / OFF

F-19978 A

REVISIONS

A	ORIGINAL RELEASE					

376-00700 (12 PLCS)

F RANGE
BT > 1
BR > 2
BS > 4

INT / EXT
BP >
C17 >
OUTPUT #2
CU >
CW >
OUTPUT #1
C19 >
C21 >
TRIG
CY >

EXT DR
C10 >
CL >
C4 >
CD >
B19 >
BW >
C2 >
CB >
GND
B21 >
BY >
C3 >
CC >
B20 >
BX >
C1 >
CA >
-15V
+5V
+15V
+15

HI FREQ

400-19976

NOTES: (UNLESS OTHERWISE NOTED)
1. ALL RESISTORS ARE IN OHMS, 1/4W, 5%.
2. ALL CAPACITORS ARE IN μf.
3. ALL NPN TRANSISTORS ARE 663-00070.
4. ALL PNP TRANSISTORS ARE 663-00071.
5. ALL DIODES ARE 376-00022.
6. ALL ICS, PIN 14 Vcc, PIN 7 GND.
7. IC 1-6 ARE MC 7490P, OR SN7490N
8. IC 7 IS SN74196N.
9. IC 8 IS 665-00057.
10. IC 9-11,13,14, ARE 665-00053.
11. IC 12 IS 665-00062.
12. REFERENCE DRAWINGS.
P.C.B. FAB. 400-19976.
" ASSY. 401-19977.

MATERIAL LIST

E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA

TITLE:
SCHEMATIC: P.C.B.
TYPE B
CLOCK BOARD

MPPS 1501
F- 140-19978 A
SHEET NO. 1 OF 1

400-19977 / 1501

REVISIONS						
REV	REVISION	DATE	DRAWN	CHK'D	APP'D	ECO
A	ORIGINAL RELEASE	—	—	—	—	—
B	EXTENSIVE REVISIONS SEE CBS. REV A	4.17.72	ABH	—	—	—
C	PILOT RUN EVALUATION SEE CBS. REV B	4.19.72	ABH	GW	WW	574

F-20459 C

400-20457

NOTES: (UNLESS OTHERWISE NOTED)
1. ALL RESISTORS ARE IN OHMS, 1/4 W, 5%.
2. ALL CAPACITORS ARE IN μF.
3. ALL NPN TRANSISTORS ARE 663-00070.
4. ALL PNP TRANSISTORS ARE 663-00071.
5. ALL DIODES ARE 376-00022.
6. ALL IC'S, PIN 7 GND, PIN 14 Vcc.
7. IC1 IS 665-00080, IC2 & 3 ARE 665-00053.
8. REFERENCE DRAWINGS
   P.C.B. FAB. 400-20457.
   " ASSY. 401-20458.
10. Q76-Q79 ARE 663-00129
11. RESISTORS R96,97,98,114,115,116,119,122,123,124,129, ARE POWER FILM RESISTORS.

MATERIAL LIST

E-H RESEARCH LABORATORIES, INC. OAKLAND, CALIFORNIA

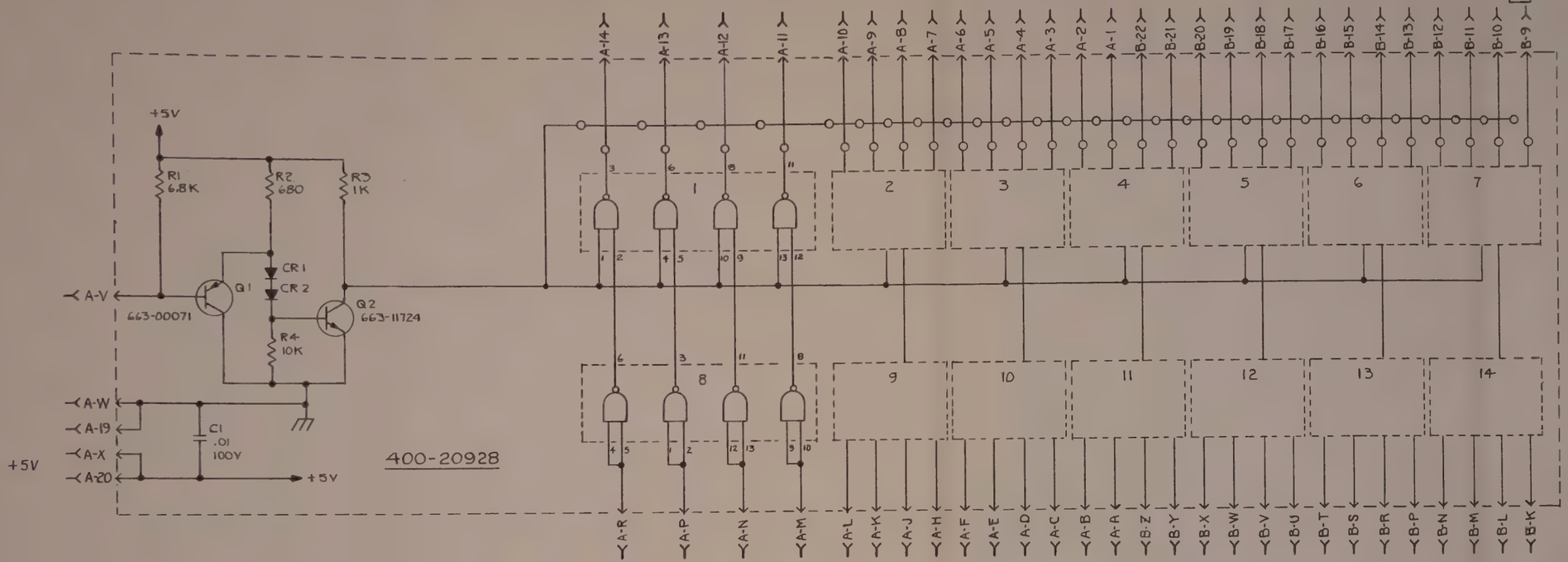
TITLE: SCHEMATIC: P.C.B. TYPE C OUTPUT BOARD

	INITIALS	DATE	MODEL 1501
BOARD	RDA	1.10.72	
ECO'D	Grad	4-17-72	F-140-20459 C
APP'D		22	

SHEET NO. 1 OF 1 SHEETS

REVISIONS						
ISSUE	REVISION	DATE	DRAWN	CHK'D	APP'D	ECO
A	ORIGINAL RELEASE	—	—	—	—	—
B	REVISED SEE OBS. REVISION A	3-15-72	RM	[illegible]	[illegible]	350 3-7

D-20930 B



NOTES: (UNLESS OTHERWISE NOTED)

1. ALL DIODES ARE 376-00022.
2. ALL RESISTORS ARE IN OHMS, 1/4W, 5%.
3. ALL CAPACITORS ARE IN μf.
4. ALL ICS, PIN 14 Vcc, PIN 7 GND.
5. ALL IC CIRCUITS IDENTICAL, WITH PIN NO'S AS SHOWN.
6. IC 1-7 ARE MC 3004P.
7. IC 8-14 ARE 665-00053 FOR NEGATIVE LOGIC, (SHOWN).
8. IC 8-14 ARE 665-00055 FOR POSITIVE LOGIC. (NOT SHOWN).
9. REFERENCE DRAWINGS.
   P.C.B. FAB. 400-20928.
   " ASSY. 401-20929.

ITEM NO.	PART NO.	DESCRIPTION	QTY

MATERIAL LIST

UNLESS OTHERWISE SPECIFIED
SCALE
FRACTIONAL ± 1/64
DECIMALS .XX = 03
± .XXX = 010
ANGLES ± 1°
DO NOT SCALE DRAWING
FINISH

E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA

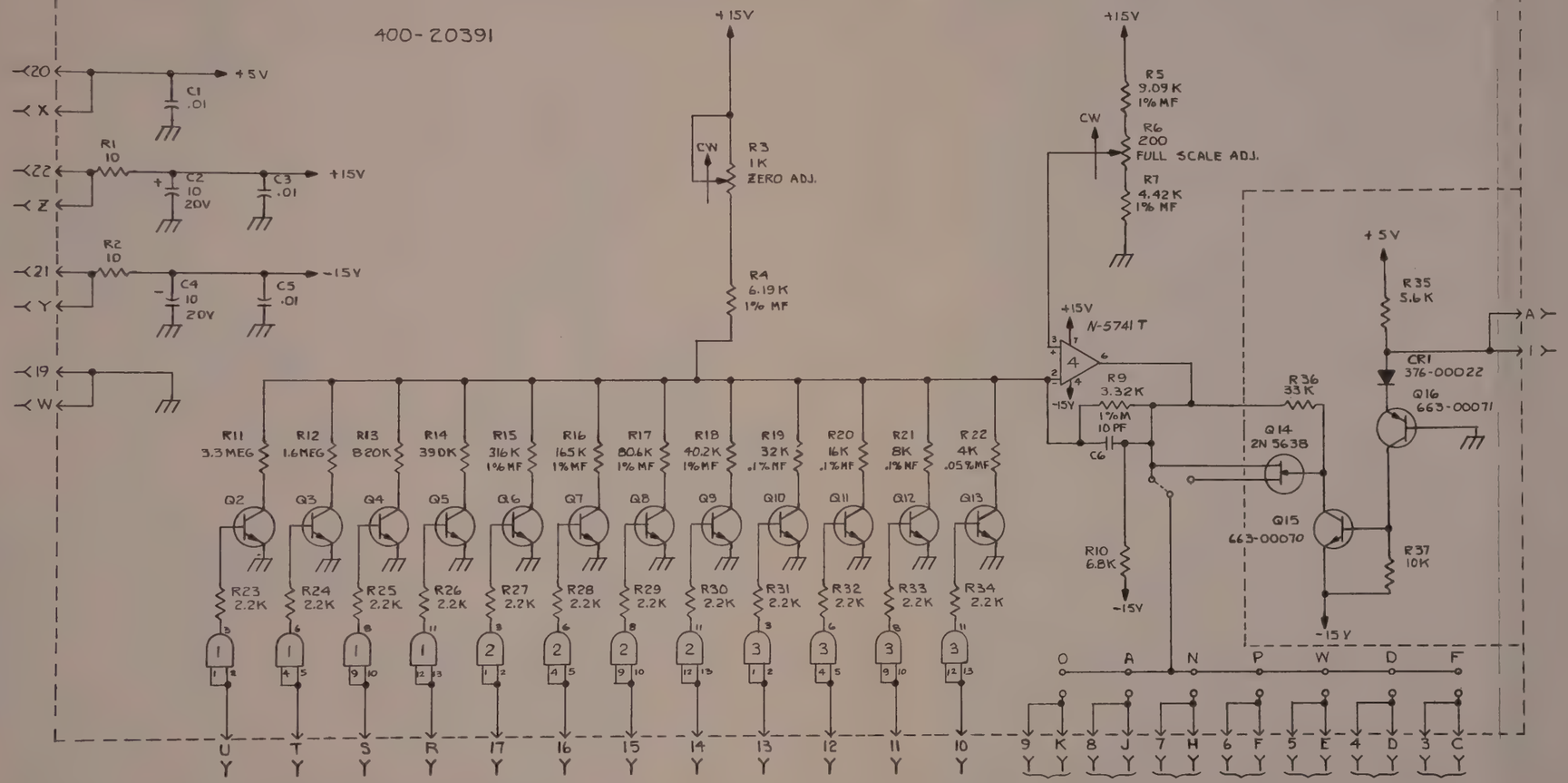
TITLE: SCHEMATIC: P.C.B. BUFFER BOARD

	INITIALS	DATE	MODEL 1501
DRAWN	RM	1.10.72	140- D-20930 B
CHK'D	[illegible]	2-14-72	
APP'D			SHEET NO 1 OF 1 SHEETS

NEXT ASSY 401-20929
REV'D 1
USED ON 1501

D-20933	REVISIONS					
			DATE	DRAWN	CHK'D	APP'D
A	ORIGINAL RELEASE		—	—	—	—
B	REVISED SEE OBS. REVISION A		5.2.72	KBM	[illegible]	[illegible]
C	DELETE Q1 & R8		1.7.72	[illegible]	[illegible]	[illegible]

400-20391



NOTES: (UNLESS OTHERWISE NOTED)

1. ALL RESISTORS ARE IN OHMS 1/4 W 5% CARBON.
2. JUMPER OUTPUT FOR APPROPRIATE FUNCTION
3. ALL MF RESISTORS ARE 1/4 W, 1% @ 70° C.
4. ALL CAPACITORS ARE IN MF
5. CIRCUITRY IN DOTTED LINES USED ON MPPS BOARD ONLY.
6. Q1 - Q13 ARE 663-00070.
7. I.C. 1-3 ARE 665-00053 ON NEGATIVE TRUE LOGIC BOARD
8. I.C. 1-3 ARE 665-00055 ON POSITIVE TRUE LOGIC BOARD.
9. REFERENCE DRAWINGS.
   P.C.B. FAB 400-20931.
   " ASSY 401-20932.

ITEM NO.	PART NO.	DESCRIPTION	QTY

MATERIAL LIST

UNLESS OTHERWISE SPECIFIED
SCALE
FRACTIONAL ± 1/64
DECIMALS: ± .XX = 03
± .XXX = .010
ANGLES: ± 1°
DO NOT SCALE DRAWING
FINISH:

E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA

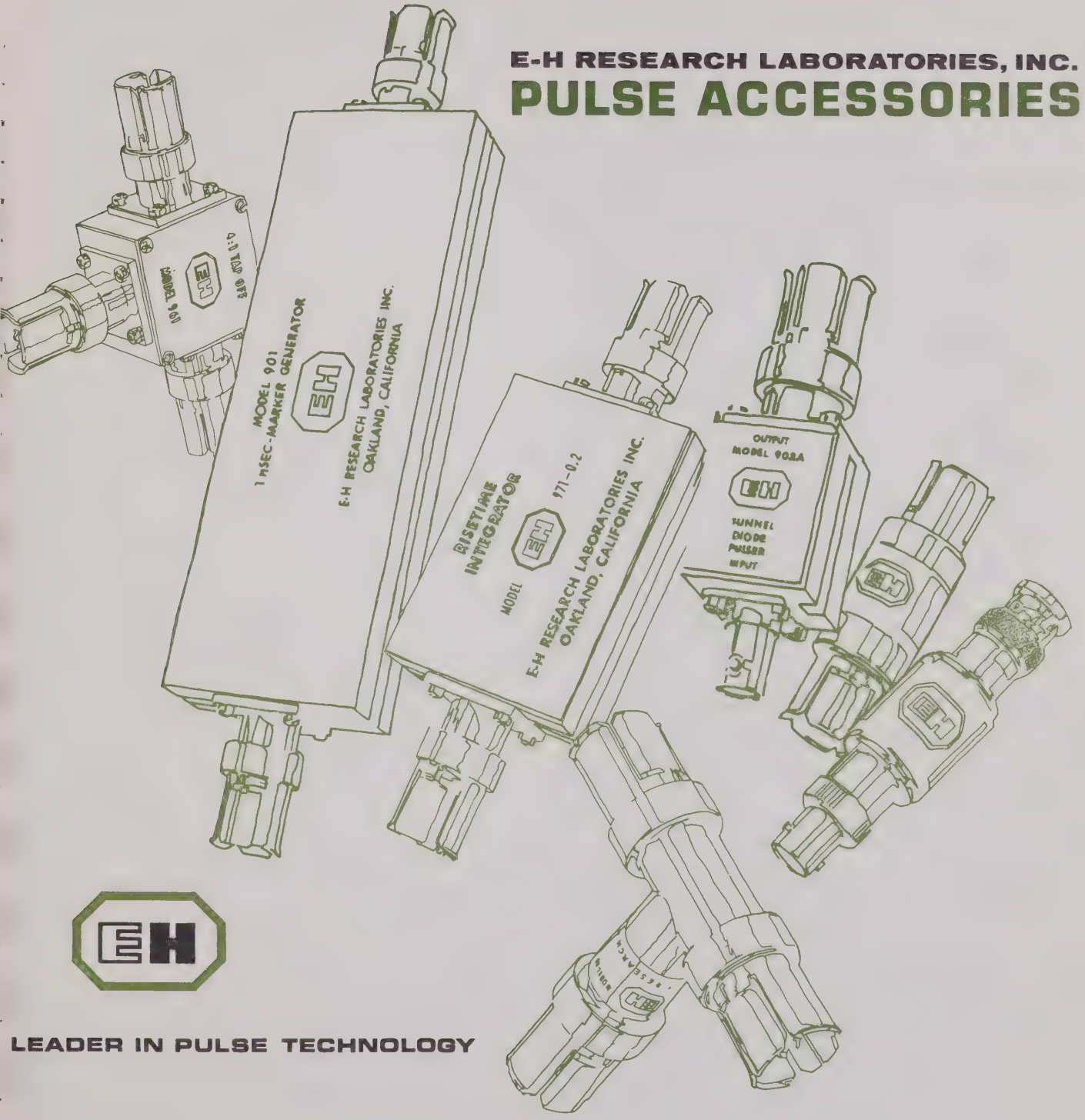
TITLE
SCHEMATIC, PARALLEL
D/A CONVERTER BOARD

	INITIALS	DATE	MODEL 1501
DRAWN	ABM	11-15-71	140- D-20933 ISSUE C
CHK'D	[illegible]	12-1-71	
APP'D			SHEET NO 1 OF 1 SHEETS

1501 USED ON | 7 REQ'D | 401-20932 NEXT ASSY

E-H RESEARCH LABORATORIES, INC.

PULSE ACCESSORIES



LEADER IN PULSE TECHNOLOGY

model 901 MARKER GENERATOR

The Model 901 Marker Generator is designed to convert a fast risetime voltage step into a train of time markers spaced precisely 1 nanosecond apart. The voltage output is proportional to the second time derivative of the leading edge of the input pulse.

SPECIFICATIONS

Marker Period . . . . . 1 nanosecond

Input Pulse Requirements . . . . . approx. 100 ps risetime; pulse width greater than total markers to be used.

Marker Accuracy . . . . . ±0.3% non-cumulative from one marker to the next. Marker intervals are measured from either the peaks or the crossover point. Accuracy of ±0.1% is available on request.

Output Termination . . . . . 50 ohms

Input Termination . . . . . 50 ohms

Maximum Input Power . . . . . 0.1 watt minimum average

Attenuation Factor . . . . . each marker's amplitude is approximately 1 dB down from previous marker.

Price $220

model 902A TUNNEL DIODE PULSER

The Model 902A contains a tunnel diode mounted in a high-frequency strip-line and supplies a 450 millivolt output with a risetime less than 100 picoseconds. This device may be driven with any period function such as a sine wave, square wave, ramp, etc. The Model 902A requires no power source other than its drive input.

SPECIFICATIONS

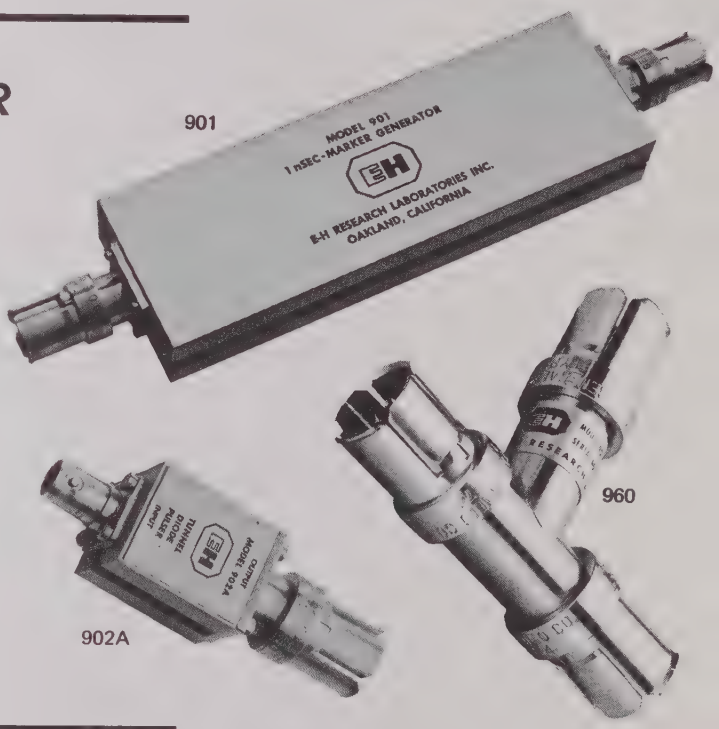
Polarity . . . . . negative; positive on request

Pulse Distortion . . . . . less than 10% (typically 5%)

Minimum Input Amplitude . . . . −5 volts peak into 50 ohms

Maximum Peak Voltage Input . . . . . 15 volts

Price $190



model 960 100:1 TAP-OFF

The Model 960 is a unique accessory in our product line: it is now possible to terminate a pulse system into 50 ohms and still observe the waveform without using the 50-ohm input impedance of the sampling oscilloscope as the load. This permits a 1 A pulser to be terminated with an adequate load, and still allows the pulse waveform to be observed without introducing distortion into the system.

The 960 has a risetime of 100 ps which is adequate for use with fast risetime pulsers such as the E-H Model 125A. With the advent of the 125A pulse generator and the 960 tap-off, an effective time domain reflectometry system may be set up with the use of the sampling scope.

SPECIFICATIONS

Risetime Input to Sidearm . . . . . less than 100 ps

Distortion Introduced Input to Output . . . . . less than 2%

Tap-Off Ratio . . . . . 100:1, ±3% into matched sidearm

Tap-Off Termination . . . . . oscilloscope connection must be terminated in 50 ohms for 100:1 ratio

Tap-Off Arm Distortion . . less than 2% on 300 ps time scale, less than 6% on 100 ps time scale

Duty Cycle . . . . . 50% at 50 volts

Connectors . . . . . General Radio Type 874

Price . . . . . $ 90

model 961 *TDR TAP-OFF*

The 961 TDR Tap-Off is a 50-ohm line-sampling device designed to be used for time-domain reflectometry with the E-H Model 125A Pulse Generator. It delivers a 6 volt 300 ps step to the device under test with a 4:1 monitor tap-off ratio.

SPECIFICATIONS

Risetime Input to Sidearm ..... less than 300 ps

Distortion Introduced Input to Output ..... less than 2%

Input to Output Ratio ..... 1.66:1 ±5% (10–6)

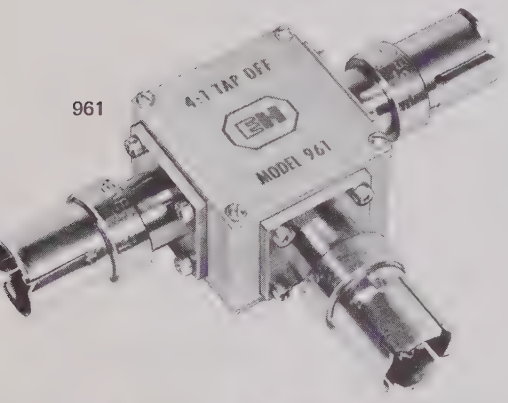
Tap-Off Ratio ..... 4:1 ±5% (output to arm)

Tap-Off Termination .....50 Ωscope input impedance forms the completion of arm

Tap-Off Arm Distortion ..... less than 2% on 300 ps time scale

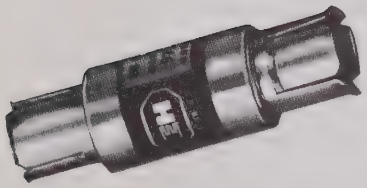
Duty Cycle ..... 10% at 10 V, maximum

Price $190



961

971


972

model 971 *RISETIME INTEGRATOR*

The Model 971 is a precision 50-ohm strip-line low-pass filter which is a useful pulse generator accessory for integrating fast-rising pulses to slower, precisely known, rise and fall times.

The Model 971 is made up of four half-section constant-k low-pass filters and is balanced so that either port may be used as an input. The specified risetime of the device is dependent on having an input much faster than its output risetime. A general rule would be to require the input to be ten times faster than the specified output. For inputs that do not meet this requirement, the resultant output risetime is equal to the square root of the sum of the squares of the input pulse risetime plus the risetime of the Model 971.

SPECIFICATIONS

Input Pulse Polarity .....positive or negative

Risetime ..... 0.2 ns, 0.5 ns,1 ns, 2 ns and 5 ns

Accuracy ..... ±10% from 10% to 90% points with an input ten times faster than the specified output risetime.

Overshoot ..... less than 5%

Price $170

model 972 *PULSE TRANSFORMER*

The Model 972 is a 50-ohm to 50-ohm inverting transformer which has an extremely fast risetime. The 972 was designed primarily to invert the 120E pulse generator output but will find many other useful applications in pulse work, such as dc isolation, and matching which requires 1:1 impedance ratios.

SPECIFICATIONS

Risetime .....less than 0.25 ns

Distortion .....5% on a 300 ps time base

Pulse Width ..... maximum 1 μs at 10 V with 37% droop.

Price .....$ 90

model DT *DC RESTORER*

This diode device eliminates baseline shift in ac-coupled, nanosecond-pulse systems. The Model DT clamps to 0 volts.

SPECIFICATIONS

Peak Input ..... 20 V

Attenuation ..... approximately 10%

Uses ..... DTP for positive pulses, DTN for negative pulses.

Price ..... $ 60

model RT *RISETIME INTEGRATOR*

This device is used to produce known, repeatable, fixed times from a fast pulse input.

SPECIFICATIONS

Standard Times ..... 5, 10, 20, 50, 100 ns (special times available on request)

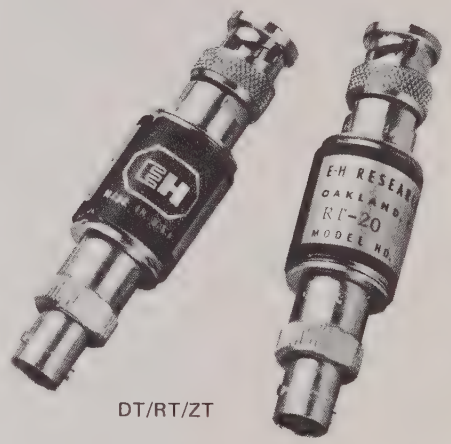
Accuracy ..... ±10%

Maximum Average Input ..... 500 mA

Connectors ..... BNC

Specify risetime when ordering (e.g., RT-10 = 10 ns).

Price ..... $ 35



DT/RT/ZT

model ZT *PULSE TRANSFORMER*

This nanosecond transformer is used for impedance matching or inversion. Impedances of 50, 93, 125, 185, or 200 ohms are available. Any combination input to output with or without inversion can be accomplished. BNC connectors are provided.

ORDERING INFORMATION FOR THE MODEL ZT

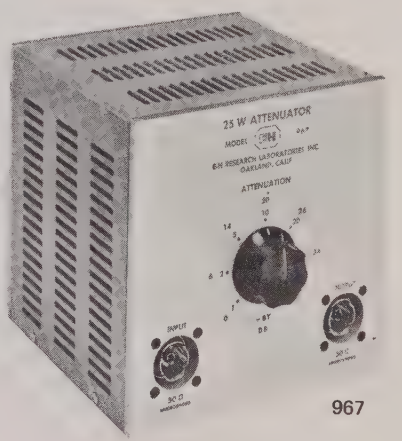
Input Impedance: specify first digit if below 100 ohms or first two digits if 100 ohms or above.

Output Impedance: same as above.

Inversion: if inversion is required add an X at the end of the model number.

Example: Model ZT-5-20X: 50 ohms input impedance; 200 ohms output impedance; inverted output.

Price ..... $ 35



967

model 967 *ATTENUATOR*

The E-H Model 967 Variable Attenuator is a 50-ohm high power switching attenuator for fast-pulse systems.

Features of the 967 include:

1. Less than 2% pk–pk clutter at 5 ns
2. 1/2/5/10/20/50/100:1 steps
3. 25 watt average dissipation

Price $290

E-H RESEARCH LABORATORIES, INC.

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In Europe: E-H Research Laboratories (Ned) N.V., Box 1018, Eindhoven, The Netherlands, Telex 51116
In Japan: Iwatsu Electric Co., Ltd., No. 7-41, 1-chrome Kugayama Suginami-Ku, Tokyo 167, Japan

TP8M/PA0571

Prices and technical data subject to change without notice – All prices F.O.B. Oakland, California

CHANGE INFORMATION

The following types of changes are found in this Section:

Corrections--
changes due to errors in text or illustrations

Additions--
new text or new illustrations to supplement original manual

Revisions--
new text or new illustrations to up-date original manual

Options--
information on non-standard accessories or options available for this instrument

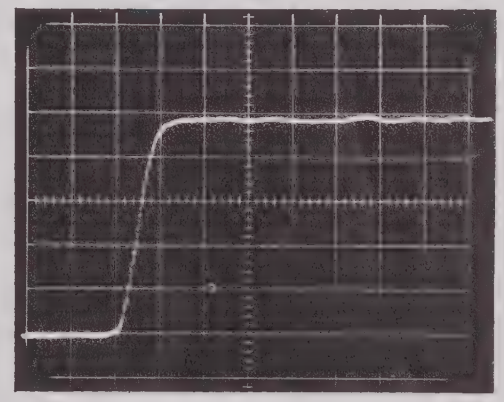
Modifications--
information on special features of a custom-designed instrument

technical data

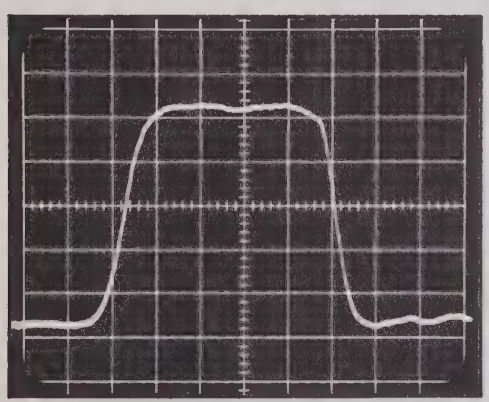
MODEL SAS 5009B SAMPLING OSCILLOSCOPE

7 GHz BANDWIDTH

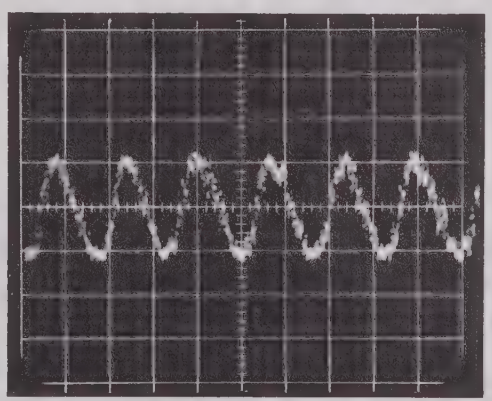
7 GHz TRIGGER BANDWIDTH



500 ps/cm; 200 mv/cm



1 ns/cm; 100 mv/cm



12 GHz Sine Wave

The Model SAS - 5009B is a field proven sampling Oscilloscope providing the most accurate measurement capability possible in the DC to 7 GHz range. It is a complete dual trace system consisting of main frame vertical plug-in (Type V-9B), - horizontal plug-in (Type H-9Y).

The reliability and accuracy of the SAS - 5009B has been customer proven over the past 2 years. The unit was developed and is manufactured by IWASAKI COMMUNICATION APPARATUS CO., LTD. The standard E-H customer warranty applies to the SAS - 5009B and Factory Service is available thru E-H Service Centers.

MODEL SAS 5009B SAMPLING OSCILLOSCOPE

LABORATORY MEASUREMENTS TO 12 GHz AND BEYOND

HORIZONTAL AND VERTICAL PLUG-IN UNITS

LARGEST SAMPLING DISPLAY SIZE AVAILABLE.
TRUE 10CM X 10CM SQUARE CRT.
EDGE-LIT NO PARALLAX INTERNAL GRATICULE.
BEAM FINDER LOCATES OFF-SCREEN SIGNALS.
50Ω AMPLITUDE CALIBRATOR.
ALL SOLID STATE
A SECOND-GENERATION 7 GHZ SAMPLING OSCILLOSCOPE
INSTANT TRACE-READY TO USE IN 10 SECONDS

SPECIFICATIONS

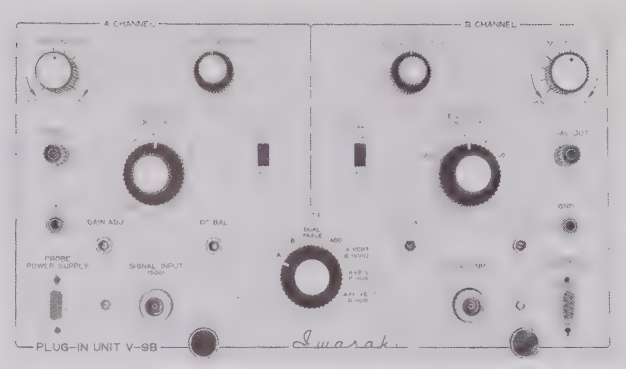
MAIN-FRAME

Screen Size:	Square 10 x 10 cm display area.
Graticule:	Edge-lit no parallax internal graticule.
Accelerating Potential:	3 kv.
Amplitude Calibrator:	.1, .2, .5, 1v into 50Ω. 10 Hz square wave. Switched .1, .2, .5, 1v p-p 10 Hz square wave into 50Ω.
Amplitude Calibrator Accuracy:	±3% into 50Ω.
Blanking Input:	30v p-p. Rear binding post input.
Plug-in Units:	Accepts V9B Sampling Vertical Plug-in Unit, H9Y sampling Timing Unit.
Beam Finder:	Locates off screen signals quickly. By pressing beam finder, signals are limited to 8 x 8 cm display, no matter what signal amplitude. Shows polarity of off-screen signal.

EASY MAINTAINABILITY:

CIRCUITRY ON PLUG-IN CIRCUIT BOARDS, PROVEN SOLID STATE CIRCUITRY, ROTARY SWITCHES HAVE PLUG-IN SOCKETS, READILY ACCESSABLE COMPONENTS, STANDARD E-H WARRANTY, SERVICE AVAILABLE THROUGH ALL E-H SERVICE CENTERS.

SAMPLING
VERTICAL PLUG-IN UNIT
V-9B



7 GHZ BANDWIDTH (-3db).

<50 pSEC RISETIME.

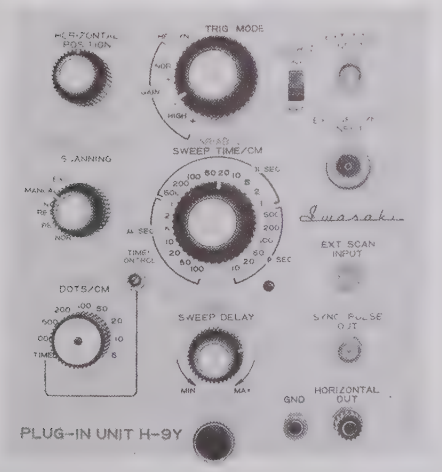
ONLY ONE PLUG-IN NEEDED FOR BOTH PULSE AND SINE-WAVE WORK.

ALL SOLID STATE CONSTRUCTION.

VERSATILE DISPLAY CAPABILITY FOR PHASE AND HIGH FREQUENCY RATIO MEASUREMENTS.

(BOTH A CHANNEL AND B CHANNEL)

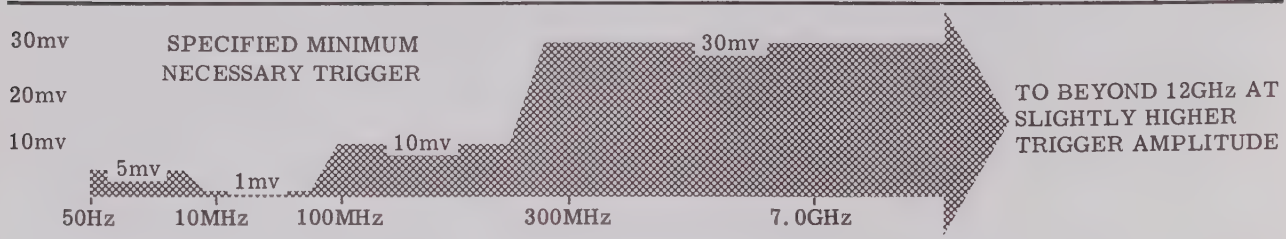
Bandwidth:	DC to 7 GHz (-3db down).
Risetime:	Less than 50 ps.
Sensitivity:	10, 20, 50, 100, 200 mV/cm. Variable control increases sensitivity up to 2.5 times.
Noise:	Less than 20 mV p-p.
Input Impedance:	50 ohms.
Input Connectors:	Type N or GR.
Operating Modes:	Individual display of either A or B channel. A and B channels dual-trace. Add sum or difference of A and B channels. A chan. vert., B chan. horiz (lissajous). A + B vert., B horiz. A + B vert, -B (inverted).
Time Difference Between Channels:	Less than 20 ps.
Vertical Signal Output	
Output Voltage:	12 times input signal voltage.
Output Impedance:	≅ 47 k.



SAMPLING
HORIZONTAL PLUG-IN UNIT
H-9Y

TRIGGER CAPABILITY:

GREATER THAN 7 GHZ BANDWIDTH PLUS HIGH SENSITIVITY.
SINGLE KNOB TRIGGERING CONTROL TO BEYOND 12 GHZ.
WIDE AMPLITUDE RANGE — VOLTS INSTEAD OF MILLIVOLTS.



External Input Impedance:	50 ohms.
Connector	<300 MHz, BNC. >300 MHz, Type N.
Jitter:	Less than 20 picoseconds.
Sweep time:	10, 20, 50, 100, 200 and 500 pS-CM. 1, 2, 5, 10, 50, 100, 200, and 500 nS/CM. 1, 2, 5, 10, 20, 50, and 100 μS/CM. Continuously variable between each step. Variable control increases sweep speed up to 2.5 times.
Sweep Accuracy:	5%.
Sweep Delay Ranges:	5 nsec/cm and faster — 50 nsec.; 50, 20, 10 nsec/cm; 500 nsec.; 500, 200, 100 nsec/cm; 5 μsec.; 5, 2, 1 μsec/cm; 50 μsec.; 50, 20, 10 μsec/cm; 500 μsec.; 100 μsec/cm 1 msec.
Minimum Delay Time:	Less than 45 nS (when SWEEP TIME/CM is 10 PS/CM to 5 ns/CM).
Sampling Density:	5, 10, 20, 50, 100, 200, 500, 1000 dots (samples)/cm. Timed position variable between ≅ .7 sec/sweep to 2 minutes/sweep for X-Y or Y-T recorder use.

SWEEP MODES

Timed
Single Scan
Manual Scan
External Scan

Ext. Scan Impedance:	More than 10 K.
Sensitivity:	Continuously variable between 60 mV/CM and 250 mV/CM.
Max. Sampling Frequency:	100 KHz.
Sync. Pulse Output:	
Voltage:	-2V (into 50 ohms).
Repetition Frequency:	Equal to sampling frequency.
Time:	15 ns before minimum delay.
Connector:	BNC.
Horizontal Signal Output:	
Voltage:	0.17V/CM.
Output Impedance:	Approximately 10 K.

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1501 PERFORMANCE VERIFICATION

Assuming:

1. Power supplies have been checked.
2. D/A cards have been set.

Equipment:

1. Controller.
2. Scope (Tek 661 w 4S1 & 5T3) or equiv.
3. Freq. counter.
4. Appropriate pads and cables.

Order of Procedure:

1. Clock
2. Width
3. Delay
4. Ext. clock functions
    a. Ext. drive.
    b. Asynchronous Gate (Gate off).
    c. Synchronous Gate (Gate on/off).
5. Amplitude
6. Polarity
7. Offset
8. Tr
9. Ramps
10. Attenuator and distortion
11. Double pulse
12. Int/Ext when applicable 1501-3.

Procedure:

1. Clock.
   Using counter, monitor output of 1501. Check the 100, 500 and 999 counts for each range. There are eight ranges encompassing the frequencies from .5Hz thru 50MHz. Ranges are 0 thru 7. Using range #6 as an example, check all counts, then set.

   999 count 5MHz
   100 count 500KHz
   500 count 2.5MHz
   spec: $\pm$5%

Clock will normally drift approximately 2% when switching from 100 to 999 count. A short wait before adjusting will allow for stabilization.

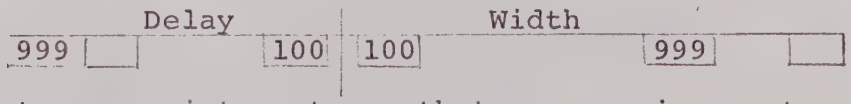
Adjust: 1 - 999 count
2 - 100 count
3 - 500 count

Not an essential order but seems to be most convenient. Some interaction will make it necessary to rock the pots into their proper settings.

2. Width.
Using 661/4S1/5T3 or equivalent, monitor output.
Six ranges from 10 ns to 10ms ±5%
±3ns.

3. Delay.
Same as width

Width & Delay Board

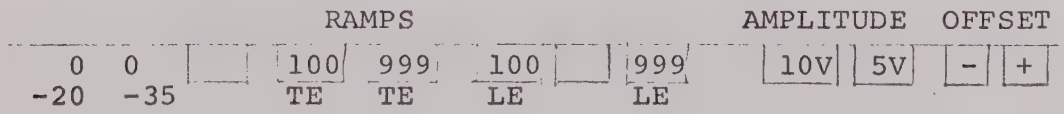


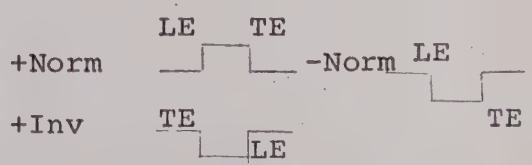
Adjust appropriate pots so that a range is exact. Check all other ranges for 5% tolerance. Some slight readjustment may be necessary. On the higher delay ranges use the double pulse function for ease of observation.

4. Check ext. drive and gate functions.

a. Ext. drive: Pos 1.5V to 5V, 50MHz.
b. Asynchronous Gate: Gate off only ≈ 2.5V req.
c. Synchronous Gate: Gate on or off - pos. 1.5V req.

OUTPUT BOARD





5. Amplitude.
Use Tek 661/4S1/5T3 or equivalent and maintain 50Ω environment with pads and cables, check all counts.

Set: 999 count 10V
100 count 5V } ±5%

Check all polarities for 5% tolerance. Adjust amplitude pots as necessary.

6. Above.

7. Offset.
Use Tek 661 or DVM. If DVM is used, turn off clock, check all counts.

With 000 offset, baseline must be within 50MV of ground in either offset polarity. At 999 count, set offset pots on output board for ±5% of ±5V.

8. Rise & Fall times.
Check for <3ns Tr & Tf in all polarities at various amplitudes. Usually, a check at 10V and a +5V in each polarity is sufficient.

9. Ramps.
Check carefully before adjusting.
Six ranges:
0 - Uncal. range <3ns -
1 - 5 1V/ns - 1V/us 1V/us - 100V/us

If it is necessary to adjust the ramps, the pots used are indicated on the output board as

		count
RMP2MIN	-	TE 100
RMP2MAX	-	TE 999
RMP1MIN	-	LE 100
RMP1MAX	-	LE 999

Amplitude - 10V
Check at 5V
While checking ramp times, check linearity.

10. Attenuator.
8 Ranges X1, 2, 4, 8, 16, 32, 64 & 128

While checking attenuator accuracy, check distortion through the attenuator in all polarities at both 999 and 100 amplitude counts.

Distortion must be <5% with Tr & Tf of 3ns except for X64 & X128 attenuator positions. 10MV of distortion allowed.